authoritative data on **UHF** practices

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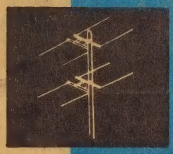
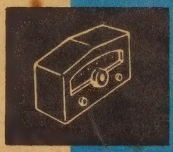
ANTENNAS
CONVERTERS
& TUNERS





UHF-I

by MILTON S. KIVER

A Howard W. Sams PHOTOFACT PUBLICATION

$1.50

UHF

ANTENNAS, CONVERTERS AND TUNERS

by MILTON S. KIVER

(UHF-1)

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HOWARD W. SAMS & CO., INC.
GRAB BAG

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FOREWORD

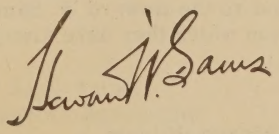
With the introduction of UHF now a reality, Television acquires a new vigor and vastly expanded coverage.

Presently planned new UHF stations will bring Television to many sections of the country which now are without TV service. In a comparatively short time, the UHF stations will far outnumber VHF stations, and it is more than likely that the Service Technician will be called upon to do more work with UHF TV receivers than with VHF sets.

UHF operation will bring with it many new problems not encountered before in Television. Consequently, all Service Technicians (experienced and newcomers alike) will welcome and need a good basic knowledge of UHF operation, equipment and problems.

This book, prepared by an outstanding authority on Television, covers those practical aspects of UHF which the TV Service Technician will require for successful work in this new field. The information is factual, accurate and applicable to everday operations. Wherever possible, comparisons are made with the better-known VHF practices.

The present volume is another in the series of PHOTOFACT publications prepared specifically to help the Service Technician stay abreast of the latest developments in Television. Like its companion volumes, it is intended to contribute toward the operation of a successful and profitable servicing business.



INTRODUCTION

There is an old and time tested saying among servicemen that new circuits bring with them new troubles. However well intentioned the design engineer and the set manufacturer may be, practical considerations force certain compromises. And because of these compromises, a service industry has sprung forth.

Today we are on the threshold of a vast new era in television. The allocation of 70 channels in the UHF region makes possible the establishment of more than 2000 television stations and the eventual purchase, by the public, of well over 50 million receivers.

The stake of the serviceman in this future is as great as that of any other segment of the industry. For while the public looks to the engineer for new developments, it must depend upon the serviceman to maintain these devices once they have been brought forth. One is as important as the other, and neither could survive alone.

UHF Antennas, Converters, and Tuners brings to the serviceman the factual information he will need to maintain the UHF devices which the engineers have just brought forth. Each phase of this new field is examined separately, first by indicating its purpose, and second, by explaining its operation. The text contains five sections, three devoted to antennas and their installation, one to converters, and one to tuners. Portions of the antenna sections appeared in a series of articles which the author was privileged to do for Radio and Television News Magazine.

In the compilation of the text material, the author is indebted to the Radio Corporation of America, Technical Appliance Corporation, JFD, Industrial Development Engineering Associates, La Pointe Plascomold, and American Phenolic Corporation. Thanks are due, too, to the Howard W. Sams organization and the limitless cooperation which they have always extended.

MILTON S. KIVER

Chicago, Illinois

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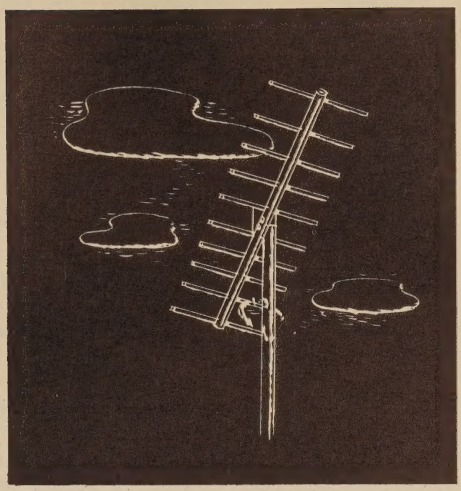
SECTION 1
UHF ANTENNAS



UHF ANTENNAS

Experience with commercial television operating at frequencies extending from 54 mc to 216 mc has demonstrated conclusively that the antenna is a vital factor in determining the quality of pictures you see on your screen. In general, the best pictures are produced when the antenna is roof mounted (or otherwise positioned at some outside point).

The importance of antennas to television reception stems from several causes. First, the frequencies to which television broadcasting has been assigned lie in a region where the losses incurred by a wave in travelling between transmitter and receiver are fairly high. Certainly they are much higher than what we find at commercial radio frequencies, 550 kc to 1700 kc. Also, because of this higher frequency operation, it is more difficult to generate efficiently large amounts of power for transmission. This is, admittedly, a temporary condition and is gradually being overcome by the development of newer tubes. But for the present it is with us.

A carefully tuned antenna, placed as far out in the clear as it is reasonably possible to do so, will go a long way toward offsetting the disadvantages of increased propagation loss and lower radiated power.

A second factor to consider are ghost images and these alone would require careful positioning of the antenna. The eye is sensitive to multiple images produced when more than one signal is received by the antenna. This is in contrast to the ear and explains,

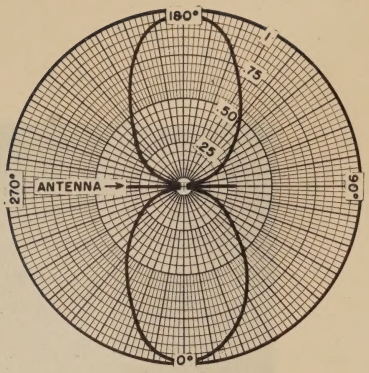


Figure 1. The Response Pattern of a Halfwave Dipole.

for example, why FM receivers can be successfully operated with loop antennas while most TV sets cannot.

The problems of reception which are encountered with VHF television receivers become even more intensified when we reach the UHF television frequencies (470-890 mc). Power becomes quite difficult to generate, losses in signal travel between station and receiver are greater, and the ability of the receiver to amplify within this region is considerably poorer. Faced with this situation, the television service man can well appreciate how important is the job of installing an antenna. The quality of the picture received can, without exaggeration, be said to depend more upon the know-how of the service man at UHF frequencies than it does now for VHF reception.

To deal with these difficulties, a host of antennas have arisen. Some of these arrays resemble those we are now familiar with, but there are many which will be strange to the television service man. To develop an understanding of these antennas and what can be expected of them, it may first be best to start with the simple half-wave dipole. Not only are many arrays nothing more than elaborations of the dipole, but when comparisons are made between the gains of different arrays, the dipole is the standard against which these comparisons are based.

The response pattern of a half-wave dipole is shown in Fig. 1. Note that a signal is best received from a direction which is at right angles (or broadside) to the antenna wires. As the angle made with the 0-180 degree line increases, the strength of the received signal decreases until, when we are facing one end of the antenna, signal reception is poorest. The dipole, then, is a directional antenna since it receives energy best from the broadside direction and poorest (or not at all) off the ends.

When we swing the dipole antenna around, the whole response pattern swings with it. Suppose the ends of the antenna are pointing

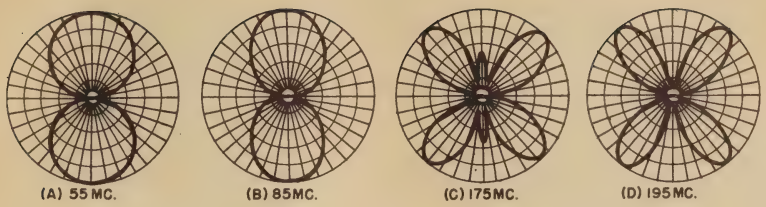


Figure 2. The Response of a 55 mc Dipole at (A) 55 mc, (B) 85 mc, (C) 175 mc, and (D) at 195 mc. (Courtesy RCA Review)

east and west; maximum response will be obtained then from signals coming from the north and south. If we swing the antenna 90°, the ends will be pointing north and south and maximum signal reception will be obtained for signals coming from the east and west.

The response of a dipole, as shown in Fig. 1, retains its figure - 8 shape even when the signal frequency is raised until it is double the value to which the antenna was originally cut. At twice the original frequency the two large lobes (or halfs) of the figure - 8 may be somewhat narrower, but the overall appearance of the response curve remains essentially the same.

However, when an antenna is employed to receive signals whose frequencies exceed twice the fundamental frequency for which the antenna was cut, side lobes appear. Fig. 2A shows the response of a dipole cut for 55 mc. Figs. 2B, C, and D show what the pattern becomes at 85 mc, 175 mc and 195 mc. In the four-lobed patterns of Fig. 2C and D, signals coming from any one of these four directions will induce maximum voltage in the dipole. Note, too, that none of these four lobes point in the same direction as the original two lobes and this might require a different positioning of the antenna. Finally, multi-lobed patterns make the array more susceptible to ghost and other interfering signals.

The number of lobes will increase as this antenna is used to receive higher and higher frequency signals. Also, there is a tendency for the larger lobes to break up into a series of smaller ones. The illustrations in Fig. 3 bring this out clearly and show why it is generally not advisable to use VHF antennas to receive UHF signals. Not only does the array lose much of its directivity, but even a reflector appears to exert little influence in cutting down the number of lobes. There are some exceptions to this behavior, and these will be brought out later.

(This fact that the response pattern of an array changes with frequency is one that is not fully appreciated by many service men. It explains, for example, why an array must be turned one way for signals of one frequency and then rotated to another direction for signals of another frequency. It could also explain why the signals

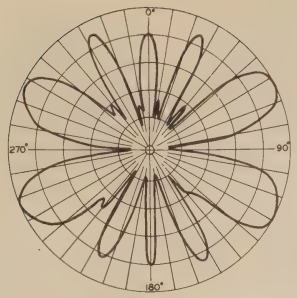


Figure 3. The Response Pattern of a 55-mc Dipole and Reflector at 550 mc. Note How Pattern is Almost Non-directional. (Courtesy RCA)

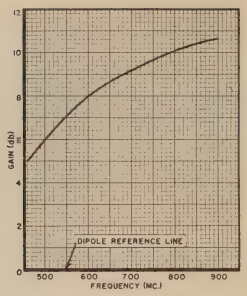


Figure 4. The 0db Line on the Graph Represents the Gain of the Reference Dipole.

for one station might be strongly received while reception of another station located in the same general area might be poor*.)

Now, it is stated that VHF antennas are not usually suitable for use at UHF frequencies. However, if we reduce the dimensions of the VHF antenna--or, in other words, raise its resonant frequency--then it will possess the same pattern at UHF as it is at VHF. The figure - 8 pattern of a 55-mc dipole is the same as the figure - 8 pattern of a 550-mc dipole. In each case, both dipoles are cut to their resonant frequencies and we are not using a 55-mc antenna to capture 550-mc signals.

At the UHF frequencies, the wavelength is much smaller than it is at the VHF frequencies. Since antennas are cut according to wavelength, this means that the physical dimensions of a half-wave dipole at 550 mc will be 1/10 of what it is at 55 mc. This smaller physical size is convenient, because it permits easier handling, simpler supporting structure, and lower cost. It can also be employed to advantage by permitting the addition of more elements to the array. The purpose of an antenna is to intercept as much of the passing signal energy as possible. Obviously, the greater the surface area of the array, the greater the amount of energy intercepted and the more signal the set receives. Thus, even fairly elaborate arrays can be built possessing moderate dimensions.

Gain. The two most important characteristics of any antenna array, from the standpoint of the service man, is its gain and directional response. The gain of an array is a comparison of the signal power which this array develops to the signal which a thin half-wave dipole develops at the same location. Thus, a gain of 10 means that the array would develop 10 times as much power as a half-wave dipole placed at the same point.

* Obviously there are also other reasons for unequal signal reception.

Many times, the decibel (db) is used as the unit of gain. In this case, since power is being employed, the formula is

$$db = 10 \log_{10} \frac{P_1}{P_2}$$

A ratio of P_1 to P_2 of 100 would give the equivalent decibel rating of 20. This follows from the fact that the $\log_{10} 100 = 2$, and 2 x 10 equals 20 db. The 0 db line is taken as the gain of the reference dipole adjusted to resonance at each different frequency. Thus, suppose that we are told that a certain array has the gain curve shown in Fig. 4. At 500 mc, the gain of this antenna is 6 db greater than a half-wave dipole, cut to 500 mc, and placed in the same position as this array. At 600 mc, this array has a gain of 8 db greater than a half-wave dipole, cut to 600 mc. The same is true for all points along the gain curve.

Directivity. When speaking of the directivity of a directional antenna, we mean the sharpness with which the signal is confined or directed to a particular direction. It may, in a sense, be compared with the selectivity of a receiver in allowing one signal to pass through and rejecting all others. The more selective the set, the sharper and more peaked its tuning curve. In radio sets, sharp selectivity can usually be attained only when several tuning circuits are used in conjunction with each other. One coil and condenser combination, by itself, would not be adequate. It is much the same with antennas. Ordinarily several radiators must be used before a highly directive pattern is obtained. Just one or two elements, by themselves, might show definite directive effects, but these would not be as clear cut as would be obtained if a greater number of elements are used.

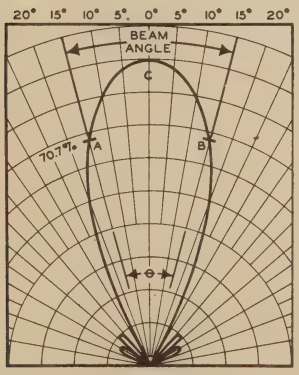


Figure 5. An Illustration of the Standard Definition of the Term "Beam Angle". (Courtesy Radio News)

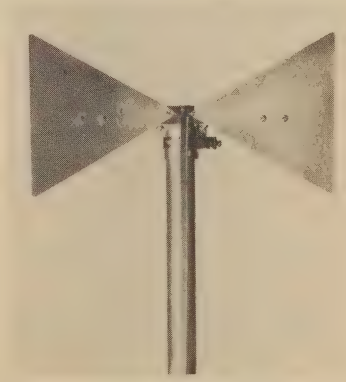


Figure 6. A Commercial Fan Dipole. Another Name for this Array is "Bowtie". (Courtesy RCA)

When speaking of antenna directivity, the term beam angle is often employed. Beam angle is the angle between the two points on a response curve at which the signal voltage is .707 (70.7%) of its maximum value. In Fig. 5, the angle between points A-B, or the angle θ, is the beam angle for this response curve. At each of these points (A and B), the signal strength is .707 of its value at point C.

UHF ANTENNAS

The half-wave dipole is the simplest type of VHF antenna and it is likewise the simplest UHF antenna. However, to increase its effective surface area, the unit is constructed of two triangles of metal, supported by a suitable insulator. See Fig. 6. By using triangular sheets of metal instead of rods, the unit becomes a broadband affair, capable of receiving all signals within the TV UHF band (470-890 mc). The response pattern of the fan dipole retains its figure - 8 pattern at both the upper and lower ends of the band. See Fig. 7. This behavior might have been anticipated in view of the fact that the highest frequency is not quite twice the lowest frequency.

Because of its somewhat altered construction, the fan dipole is capable of greater gain than the conventional dipole using thin rods. This increase, however, is quite small and in consequence the fan

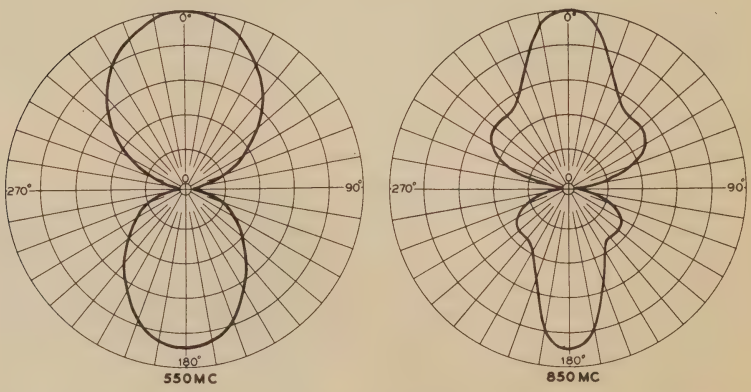


Figure 7. Directivity Pattern of a Fan Dipole. (Courtesy RCA)

dipole (by itself) provides satisfactory reception only in strong signal areas where there are relatively few ghost signals.

The impedance of a fan or triangular dipole varies with the corner angle of the dipole section. To best match 300-ohm balanced lead-in lines, the corner angle should be about 70°. See Fig. 8. Also recommended for greatest gain is an overall dipole length of 16 inches.

Fan dipoles can be stacked 2 high and 4 high, as shown in Figs. 9 and 10, to provide increased gain. For the 2-bay unit, the gain varies from a low of 4.5 db at 500 mc to a high of 8.3 db at about 850 mc. With a 4-bay array, the gain limits are 7 and 10.4 db.

In all the curves shown, 300-ohm twin lead transmission line was connected to the antennas to conduct the signal to the receiver. For a single fan dipole, the 300-ohm line attaches directly to the narrow ends of the triangular sheets. For the two stacked fan dipoles, two small rods connect similar ends together (as shown in Fig. 9) and the 300-ohm twin lead would attach to the center points of these rods. In the 4-bay array, the arrangement shown in Fig. 11 would have to be used. These matching systems are similar to those used with VHF arrays.

RHOMBIC ANTENNAS

The rhombic antenna, shown in Fig. 12, has been used to some extent for VHF reception in weak signal areas. It has broad bandpass properties, is unidirectional, possesses a sharply defined directivity pattern, and is capable of good gain. That it is not extensively employed at VHF is due principally to the fact that its dimensions are quite large and the array neither lends itself to rotation by a rotator, or to limited spaces such as apartment building rooftops where more than one array might be installed.

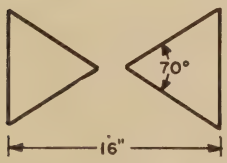


Figure 8 Recommended dimensions for the Fan Dipole.

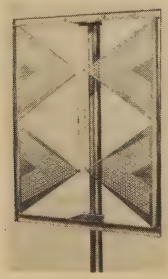


Figure 9. A 2-Bay Fan Dipole. (Courtesy RCA)

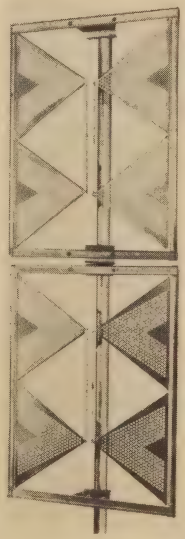


Figure 10. A 4-Bay Fan Dipole. (Courtesy RCA)

Figure 11. The Manner in which the Various Sections of the 4-Bay would be Interconnected.

Figure 12. A UHF Rhombic Antenna.

The details of a rhombic antenna are shown in Fig. 13. The length of each of the four sides (also known as legs) should be at least several wavelengths long. In fact, the longer each side, the greater the gain and the sharper the horizontal directivity pattern of the array. The angle at A varies with the length of the legs, but it generally falls between 110 - 130 degrees.* If the wires at point B are simply connected together, the array is bi-directional. But if, as is more usual, a carbon resistor having a value of 470 to 500 ohms is inserted at this point, the response pattern becomes uni-

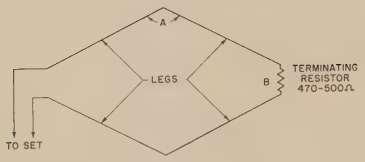


Figure 13. Details of a Rhombic Antenna. (Courtesy Radio News)

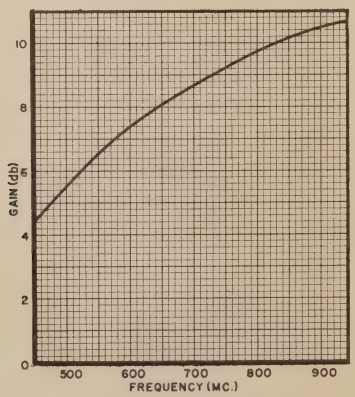


Figure 14. Gain Characteristics of the Rhombic Antenna Shown in Figure 12. (Courtesy Radio News)

* For legs which are 2 wavelengths long, an angle of 110^{o} is recommended; for legs 3 wavelengths long, the angle is 120^{o}; and for 4 wavelengths long, it is 130^{o}.

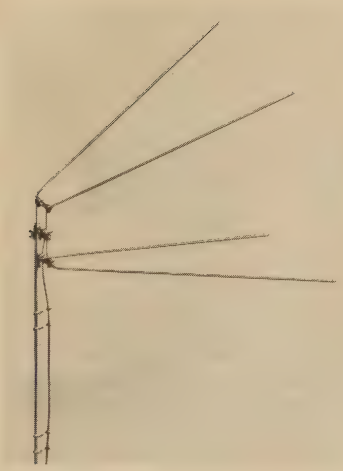


Figure 15A. A UHF Stacked "V" Antenna. (Courtesy J.F.D.)

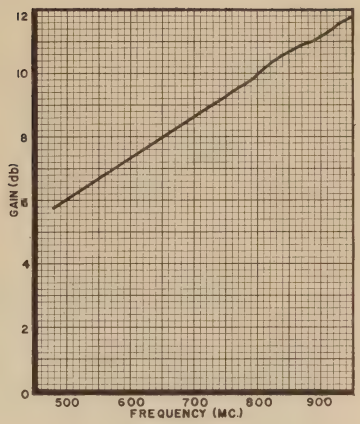


Figure 15B. Gain Characteristic of the Stacked "V". (Courtesy Radio News)

directional. The input impedance at the other end is equal to the value of this resistor, but connecting a 300-ohm twin lead here will, for all practical purposes, serve very nicely with some slight loss in gain. (Open-wire transmission line has an impedance of 450 ohms and will produce a better match.)

Rhombic antennas, because of their broadband properties, can be used easily over a 2 to 1 frequency range. Their gain (as shown for UHF array in Fig. 14) enables them to be used in relatively weak signal areas. Their sharp directivity patterns (on the order of 25° or less) indicate that they would be extremely useful in places where a broader characteristic might lead to ghost images or other interferences.

In the UHF band, making each leg length equal to 2 or more wavelengths would not result in an unwieldy array. Thus, at a frequency of 470 mc, 1 wavelength is equal to approximately 24 inches and 2 wavelengths would be 48 inches. Suitable mechanical support can be furnished by a cross-arm mast which is mounted at the top end of a pipe. The array would then be oriented with the resistor end pointing in the direction of the station.

Stacking of rhombic antennas can be employed for increased gain just as it can with any other type of array. Separation of one-half wavelength is recommended and under these conditions a gain increase of 2 db occurs over the entire band. Stacking will also increase the vertical directivity and this may reduce the number of undesirable signals which the array picks up. It will be found that reflections of waves upward from the earth tend to be more numer-

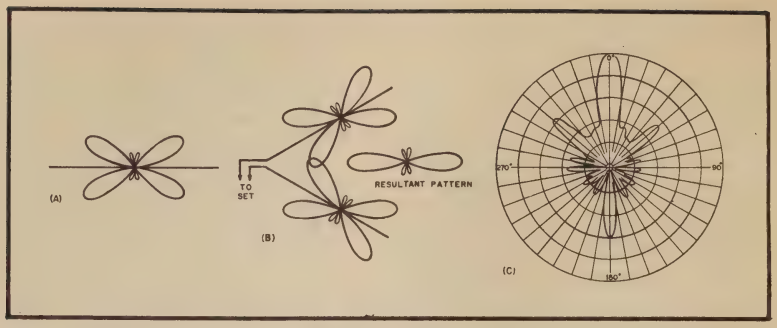


Figure 16. Formation of "V" Antenna Response. (A) Ideal Curves for Wire Longer Than 1 λ. (B) Individual Response Pattern and Resultant Pattern. (C Directional Pattern of an Actual Stacked "V". (Courtesy Radio News)

ous at ultra-high frequencies than at VHF. Hence increased vertical directivity will often prove to be highly beneficial at the higher frequencies. This is a good point to keep in mind.

STACKED "V"

A broad band UHF array which has received a considerable amount of attention is the stacked "V" antenna shown in Fig. 15. Stacked "V" (and rhombics) belong to that class of antennas known as long wire antennas. If we take a wire which is more than 1 wavelength long and use this for reception, the response pattern will be as shown in Fig. 16A. If two such wires are arranged to form a "V", the overall pattern assumes the shape shown in Fig. 16B. The response is now essentially bi-directional although a number of minor lobes do exist.

It has been found, however, that the major lobe pointing to the rear of the array can be reduced in size by increasing the diameter of the rods and this fact is frequently utilized to produce essentially a uni-directional response.

The gain of a "V" antenna is dependent on the leg length and on the value of the angle which the two wires make with each other. Gain increases more or less directly with leg length and so it would appear advisable to make each wire as long as possible. The only difficulty encountered in this respect is antenna support because if the unit is to be supported entirely at one end, the wire length cannot be too great or the array will swing back and forth in the wind and eventually break. Also, too much structural vibration frequently results in signal variation. A good compromise in physical length is between 50 and 55 inches. This is still several wavelengths long at the lowest UHF operating frequency and provides good gain.

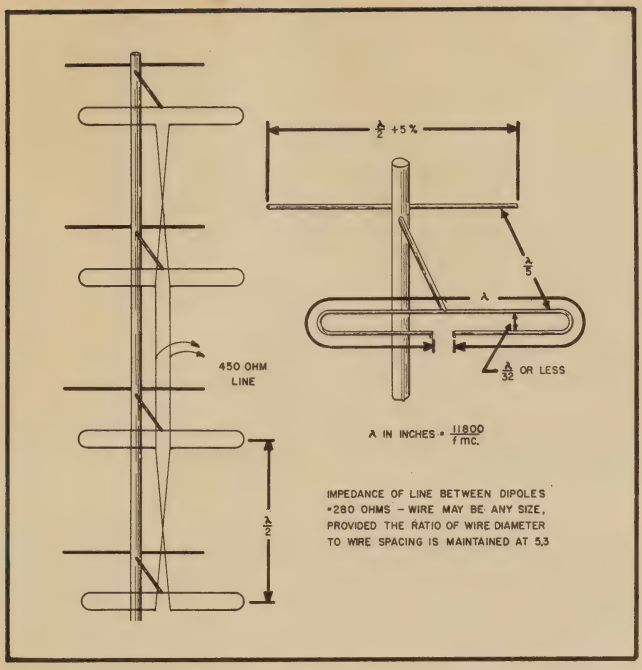

λ/2 +5%
λ/5
λ
λ/32 OR LESS
450 OHM LINE
λ/2
A IN INCHES = 11800/f mc.
IMPEDANCE OF LINE BETWEEN DIPOLES =280 OHMS – WIRE MAY BE ANY SIZE, PROVIDED THE RATIO OF WIRE DIAMETER TO WIRE SPACING IS MAINTAINED AT 5.3

Figure 17. Details on a 4-Bay UHF Array which uses Folded Dipoles and Reflectors. (Courtesy Sylvania Electric)

The best suitable "V" angle lies between 40° and 60° and the compromise figure of 50° is frequently chosen.

Stacking of two "V" antennas one-half wavelength apart (at the lowest operating frequency) provides an increase in gain while at the same time making the vertical response narrower. The two "V" sections are connected by a short length of 300-ohm line. Connection of the lead-in line is then made to the mid-point of this section. 300-ohm transmission line is used for this, too.

The simplicity of construction of this antenna, its extremely wide band coverage, plus the fact that its gain rises with frequency makes it attractive for UHF installations. A rising gain characteristic is desirable to offset the increased attenuation which occurs at the higher frequencies.

The directivity patterns of a stacked "V" antenna (Fig. 16C) show that minor lobes can cause interference in areas where secondary signals are present. However, in reasonably clear areas, the high gain afforded by this array more than counterbalances this.

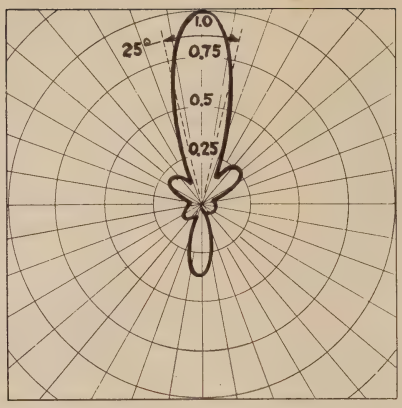


Figure 18. Response Pattern of Antenna Array of Figure 17. (Courtesy Radio News)

It may be mentioned in passing that a leg length of 55 inches is close to being a quarter wavelength at channel 2 frequencies. Thus, the stacked "V" will, in many instances, operate satisfactorily on both VHF and UHF bands.

OTHER ANTENNAS

While we have more or less skimmed over conventional VHF antennas so far as their application to the UHF band is concerned, there is no reason why they could not be employed for UHF reception. If anything, their smaller size at UHF frequencies makes them more suitable for stacking and consequent greater gain.

As an illustration, consider the 4-bay folded dipole array shown in Fig. 17. Each folded dipole is one-half wavelength long from end to end or one full wavelength all the way around. Separation between

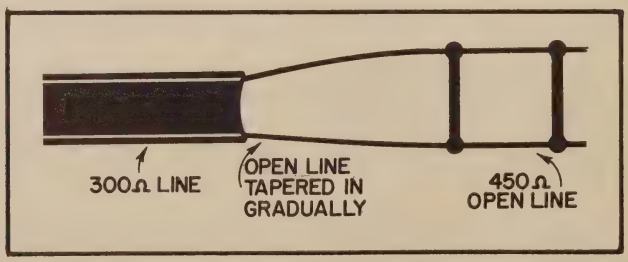


Figure 19. How to Connect a 450-ohm Line to a 300-ohm Line Without Having a Mismatch. (Courtesy Radio News)

bays is one-half wavelength while all reflectors are made 5 per cent longer than a folded dipole. The gain of this array is approximately 12 db and the directivity is such that the beam angle is only 25°. See Fig. 18. There are several secondary lobes, but they are small and can ordinarily be disregarded.

Connection between the several bays is made with commercially available 450-ohm open wire transmission line. Also, the 450-ohm line is employed to bring the signal to the receiver. The attenuation of open wire lines is considerably lower than either the familiar 300-ohm twin lead or any of the coaxial cables and, in this respect, is desirable for UHF application. However, when connection is to be made at the receiver, a mismatch occurs because receiver input impedances are either 300 ohms balanced or 75 ohms, unbalanced. To effect a match between the 450-ohm open wire line and 300 ohms input impedance, we can either use a quarter wave line having a characteristic impedance of 368 ohms or we can taper the two wires on the 450-ohm line inward until the impedance they present is 300 ohms. The taper should be very gradual, extending over a distance of at least 2 wavelengths. See Fig. 19. This serves to gradually step-down the 450-ohm open line impedance to 300 ohms, at which point direct connection can be made to the receiver.*

When the receiver input impedance is 75 ohms, unbalanced, then a matching device (known as a balun) must be inserted between the transmission line and the receiver. A balun would be required, too, between an incoming 75-ohm coaxial cable and a balanced 300-ohm receiver input. In a later section, construction of baluns will be given.

A 4-bay stacked conical is shown in Fig. 20. This is another adaptation of a very popular VHF array. Spacing between bays is one-half wavelength and connections between the four units is similar to that shown in Fig. 17.

A favorite fringe area antenna on the low bands is the yagi. Properly dimensioned, the same array can be gainfully employed for the reception of high frequency signals. Thus, the unit shown in Fig. 21 will have a gain of almost 10 db at its resonant frequency and a fairly sharp directional pattern. See Figs. 22 and 23. Of course, whether the yagi is employed at UHF or VHF frequencies, its gain falls off rapidly on either side of resonance. In areas of interference this property can be of great value; at other times the narrow bandpass can be more of a disadvantage than an advantage.

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* It may be possible to connect the open-wire line directly to receiver input (balanced) without noticeable loss of signal or the formation of ghosts. Receiver input impedances, although stated to be 300 ohms, often vary considerably above and below this value. The best test is to observe the results with and without the impedance matching section.

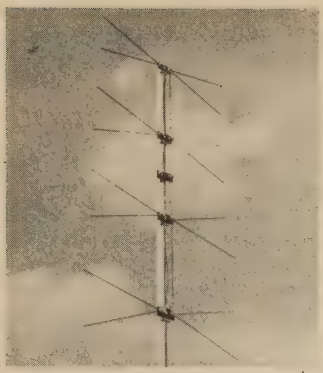


Figure 20. A Four-Bay Conical which is Suitable for UHF Television Work. (Courtesy TACO)

Figure 21. A UHF Yagi. (Courtesy J.F.D.)

(Because of the lower relative Q of tuning systems at UHF, of which the antenna is one, the yagi can be employed to receive something like 5 or 6 adjacent channels at frequencies near 500 mc. At 900 mc, this number increases to nine or ten. However, in comparison to other UHF arrays, the frequency response of a yagi must still be considered as being very narrow.)

The more elements that are added to a yagi (in this case, directors), the greater the gain and the narrower the beam angle. Also, with more elements, the input impedance presented by the dipole decreases. To present an impedance of 300 ohms, the diameter of one rod of the dipole is made larger than the diameter of the other rod. Actually, the impedance of this particular dipole, by

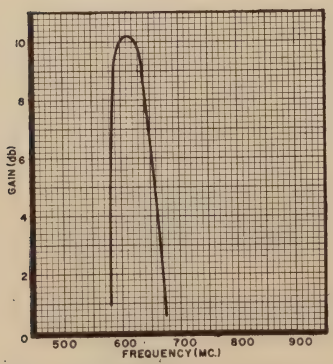


Figure 22. Gain Characteristic of UHF Yagi. (Courtesy Radio News)

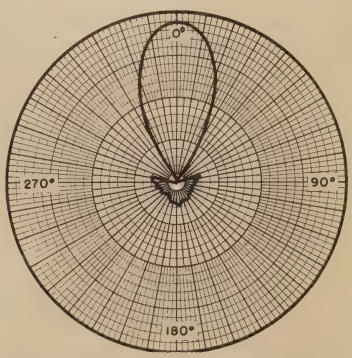


Figure 23. Directional Response of Yagi. (Courtesy Radio News)

itself, is in the vicinity of 600 ohms, however, when the reflector and directors are added, the impedance value decreases to 300 ohms. By altering the spacing and the diameter of the rods in the folded dipole, various impedances can be obtained.

ANTENNAS WITH REFLECTORS

The addition of a reflector to an antenna serves several purposes. First, it reduces or substantially eliminates reception of any signals approaching the array from the reflector side. This converts a bi-directional antenna into one which can receive signals from essentially one direction only. Secondly, it increases the gain of the array in the remaining direction.

In VHF applications, there is usually only one reflector employed and this is frequently a single rod or, at most, two or three rods, positioned about .15 to .25 wavelength behind the receiving element. While these rods do serve to reduce signal pick-up from the rear, they are far from being totally effective. A more efficient reflector would be one constructed of a solid metallic sheet (or a wire mesh of similar size) placed behind the antenna. At VHF frequencies, antenna dimensions are such that use of a sheet reflector would cause the array to become bulky and frequently difficult to erect. However, at UHF frequencies, the dimensions are sufficiently reduced so that sheet reflectors are entirely feasible. Mesh screens serve as well as solid metallic sheets. The fact that there are openings in the screen does not affect its performance as a reflector so long as the openings are on the order of .2 of a wavelength or less. Dimensions of the reflector are not critical but the edges should extend for a short distance beyond the dipole elements.

In common use, too, are parallel bars as reflectors in place of a mesh. The same considerations of small spacing apply here, also.

Two stacked dipoles with a sheet reflector made of a series of rods is shown in Fig. 24. The broader than normal width of the dipole elements tends to broaden the bandpass of the array and to keep the input impedance more uniform over the range of frequencies to be received.

Parabolic Reflectors. Parabolic reflectors are not at all new. For many years, before anyone thought of using them for the concentration of radio waves, they were employed for light beams. Their concentrating action is due to the shape of the reflecting surface and the fact that, for reflection, the incident and the reflected rays make equal angles with any line that is drawn perpendicular to the surface at the point of reflection. To understand this, refer to Fig. 25A. Here we have the ray AB hitting the parabolic surface at point A. Let the line N be perpendicular to the parabola at point A. Then, for reflection, angle α must equal angle $\emptyset$. It will be found that the reflected ray AF will pass through the focal point F.

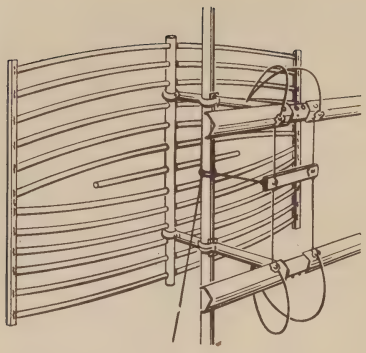


Figure 24. Two Half-wave Dipoles Using a Sheet Reflector. (Courtesy Davis Electronics)

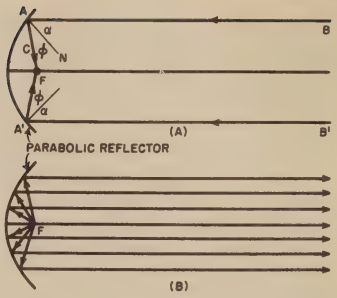


Figure 25. (A) A Parabolic Reflector Concentrates all Parallel Arriving Rays at the Focus. (B) Rays Leaving the Focus Point Travel out in Parallel Rays. (Courtesy Radio News)

Furthermore, it can be shown that all parallel rays reaching the parabolic surface will likewise meet at point F. Going the other way, rays starting from F will strike the parabolic surface and travel outward in parallel lines, as in Fig. 25B. Spherical surfaces do not possess this property. The parabolic reflector may be used either to concentrate a set of rays coming toward it or to produce a group of parallel rays. In ultra-high frequency communication, both are desirable.

It should be noted that the concentrating action or focusing occurs only when the rays arrive at the reflector along parallel lines. For all other angles of incidence, the rays do not pass through the focal point F. The reader might think this would impose a limitation on the unit, but experience has shown that radio waves coming from points as close as 3 or 4 miles away arrive essentially as parallel rays. At greater distances the effect is even more positive.

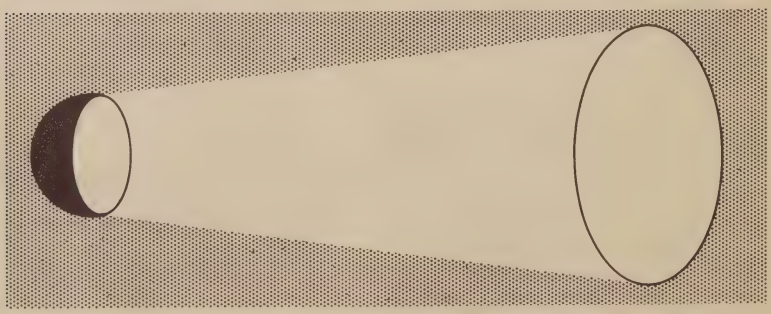


Figure 26. Radiation Beam of a Parabolic Reflector. (Courtesy Radio News)

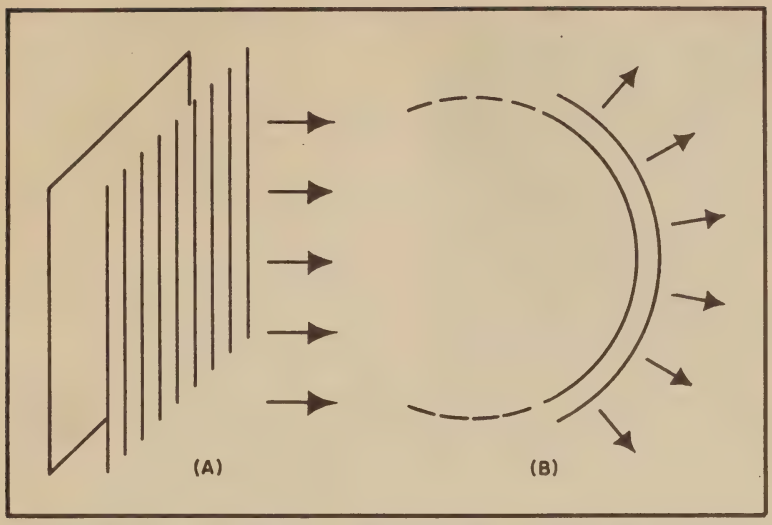


Figure 27. A Plane Wave (A) Tends to Travel in a Straight Line, Maintaining a Close Concentration of Energy. A Spherical Wave (B) Tends to Spread Out. (Courtesy Radio News)

For reception or transmission, the antenna is placed at the focal point, F. In order to achieve the proper focusing action, the antenna must be kept as small as possible. For this reason, only simple antennas are used.

The radiation beam of a parabolic reflector (known also as a rotational parabola or a paraboloid) is circular. See Fig. 26. This means that the height of the beam in the vertical plane is the same as the width of the beam in the horizontal plane. It does not mean, however, that the energy is being radiated to all points about the parabolic reflector. The energy is concentrated into a beam, like the light from a flashlight, and projected in the direction that the reflector is facing.

The ability of a parabolic reflector to concentrate energy into a narrow beam is due to its ability to take the spherical waves which are radiated by a dipole placed at its focus, and convert this energy into a plane wave.* Now, energy radiated into space will travel in a direction perpendicular to its wave front. If we have a plane wave, such as shown in Fig. 27A, then the energy will travel forward in a straight line, because this is the only direction which is perpendicular to the wave front. The energy will have no tendency

* For the purposes of explanation, it is easier to consider the parabolic reflector from the standpoint of transmission rather than reception. However, whatever is stated for one use is just as true for the other.

to spread out because all sections of the wave front, being in the same plane, will move forward in the same direction. When the wavefront is spherical all sections of the wavefront will move in a direction perpendicular to the wavefront, similar to the plane wave. However, since the wavefront surface is curved, perpendiculars drawn to the various points of the wave will not all be parallel to each other. See Fig. 27B. As a result, this energy, as it travels, will spread out producing a radiation pattern which is not as sharp or directive as that obtained with a parabolic reflector.

As a general rule, then, the directivity of any radiating system depends upon its ability to convert whatever energy it receives into a plane wave.

In order for a parabolic reflector to produce a plane wave, its shape must be truly parabolic in all directions, the antenna must be placed precisely at the focal point, and the dimensions of the antenna made small in comparison to the dimensions of the parabolic "dish". If any of these conditions are not adhered to, the radiation pattern does not remain circular and the radiated wavefront begins to curve. This causes the beam width to increase and energy is radiated off to the sides through the establishment of minor lobes. Parabolic reflectors, when carefully constructed, are capable of providing appreciable gains over that obtained from a simple dipole alone.

In order to achieve a high degree of directivity and good gain, the parabolic reflecting surface must be large in comparison to the antenna (and, in the same sense, to the wavelength of the signal). This is the chief reason why these units find application only at the ultra-high frequencies.

The gain of a parabolic is given by

$$G = \frac{4 \pi A}{\lambda^2}$$

where A = Aperture area of the reflecting "dish"
λ = wavelength of the signal to be transmitted (or received).

The aperture area of a parabolic reflector is very closely equal to the area across the mouth of the reflector. As this area becomes greater, in comparison to the wavelength of the signal, the gain increases accordingly. The angular width of the beam, between the half-power points, for the reflector is given by

$$\text{Width} = \frac{70 \lambda}{d}$$

where d = width of aperture

The response pattern of a parabolic reflector is shown in Fig. 28. There is one large lobe, the primary or principal lobe, surrounded by several small secondary lobes. Increasing the size of the reflector or decreasing the wavelength will cause the width of the

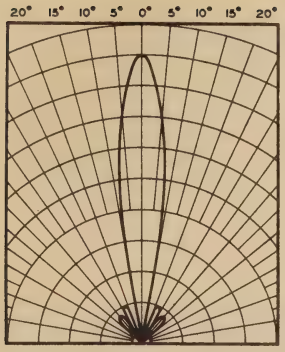


Figure 28. Response Pattern of a Parabolic Reflector.

Figure 29. A Cylindrical Parabolic Reflector. (Courtesy TACO)

principal lobe to decrease and its gain to increase. At the same time the minor lobes will decrease in size, and move in closer to the main lobe.

It is possible to use sections of a parabolic reflector instead of an entire paraboloid. The cylindrical parabolic reflector shown in Fig. 29 can provide a gain of 8 db over a resonant dipole. The vertical directivity is sharp but the horizontal directivity is somewhat broad. Where high gain is desired and the ghost problem is not serious, this array will produce excellent results. And the reduction in size from a full paraboloid permits the unit to be built more economically.

The Corner Reflector. Instead of using curved surfaces as reflectors, it is possible to use two flat surfaces which are so placed as to intersect each other at some angle, forming a corner. This type of reflector, shown in Fig. 30, is known as a "corner reflector" antenna. The driven element, usually a dipole antenna, is placed at the center of this corner angle and at some distance from the vertex of the angle. Fig. 30 shows the antenna as it could be used for the reception of horizontally polarized waves. By turning the system on its side, vertically polarized waves could be received as well. These two flat surfaces may form any angle up to the limiting value of 180°, in which position the reflector becomes a flat surface.

The response pattern of this array depends not only on the corner angle but also on the distance between the antenna and the vertex of the reflector corner. For relatively large distances (large compared to the wavelength used) a pattern containing more than one main lobe is obtained, as shown in Fig. 31. Moving the antenna in too close will affect the vertical response of the array and make it more susceptible to ground reflected signals. Since neither of the

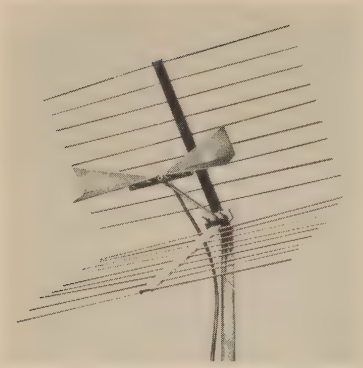


Figure 30. A Corner-Reflector UHF Antenna. (Courtesy J.F.D.)

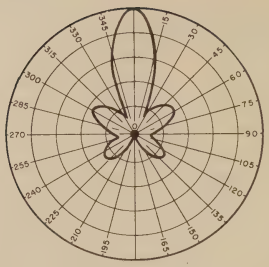


Figure 31. When the Dipole is Positioned too far from the Corner Reflector, the Response Pattern Breaks up into Several Lobes. (Courtesy RCA)

foregoing conditions are desirable, the exact positioning of the dipole must be carefully controlled.

The corner angle in the commercial array of Fig. 30 is 90° and a similar bend is placed in the dipole. The reflector bar spacing is .2 of a wavelength or less at the highest frequency at which the array is to be used. Gain over the entire UHF-TV band is high, ranging from about 7 db at 500 mc to 13 db at 900 mc. The wide bandwidth and good gain of this array make it very attractive for weak signal areas.

Horn Antennas. With the shift of commercial television broadcasting to the ultra-high frequencies, we approach the region where horn antennas, which are employed in radar, become feasible for TV. Here, again, size is the only restricting factor and only in the UHF region do these units become small enough to assume reasonable proportions.

A horn antenna can be considered as an outgrowth of a waveguide. Waveguides are very efficient hollow transmission lines which are extensively employed in high-frequency circuits to conduct energy from one point to another. If it is desired to transmit this energy into free space, the ends of the waveguide are flared out. See Fig. 32.

By flaring the ends, the energy travelling along the guide will gradually move from the guide to open space with a minimum of reflection at the point where the guide ends. In a sense, then, the flaring serves as an impedance match between the guide and the surrounding space into which the energy is transmitted. By the same token, any energy which is received would be gradually conducted along the narrowing horn until it reached the waveguide.

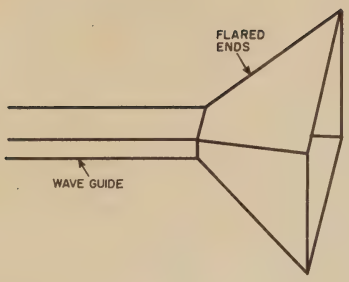


Figure 32. By Flaring Out the Ends of a Waveguide, Energy Can be sent Down the Guide and Out into the Surrounding Space with Little Reflection. (Courtesy Radio News)

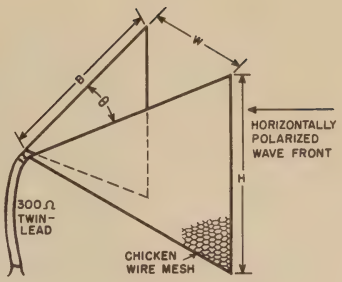


Figure 33. A Modified Horn Antenna used for TV.

Horns and waveguides may either be rectangular or circular in shape. Of immediate interest is the rectangular horn. With several modifications, this can be made into an effective TV antenna.* Rectangular horns contain four sides, but since horizontally polarized waves are used in TV transmission, both top and bottom sides of the horn can be removed. Secondly, since transmission lines rather than waveguides are used to conduct the energy from the antenna to the receiver, we can remove the waveguide and substitute the conventional 300-ohm twin lead. See Fig. 33. Now, all we need do to transform this into a practical device is to use a fine mesh wire screen in place of the two remaining solid metal sides.

From the difference in shape of the modified horn antenna, the reader may suspect that the method of computing its dimensions will also differ from other antennas. For the horn shown in Fig. 33, the height and width (or vertical side separation distance) dimensions are given by the formula:

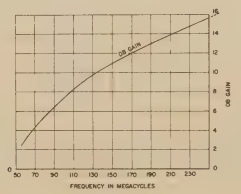


Figure 34. Gain versus Frequency for TV Horn Antenna.

* "Horn Antennas for Television" by D. O. Morgan. Electronics, October, 1951.

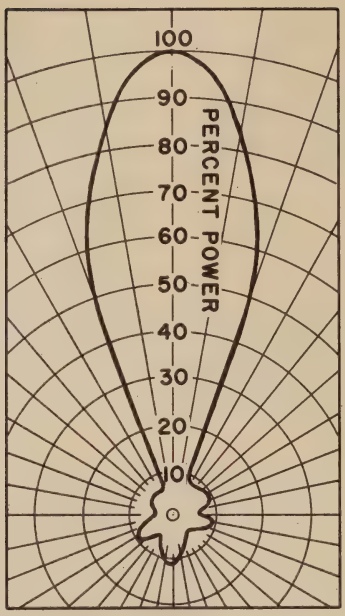


Figure 35. Directional Pattern of TV Horn Antenna.

$$H_C = W_C = \tfrac{1}{2}\ \lambda_C$$

and $B_C = \tfrac{1}{2}\ \lambda_C$ (when $\theta = 60^\circ$)

where λ_C is the lowest wavelength which it is desired to receive with this horn. Thus, if the lowest signal to be received is taken as 61 megacycles, $\tfrac{1}{2}\lambda_C$ is found equal to 8 ft.

$$\lambda = \frac{984}{f(mc)}$$

$$\lambda = \frac{984}{61}$$

$$\lambda = 16 \text{ approx.}$$

and

$$\lambda/2 = 8 \text{ ft.}$$

Now, of course, 8 feet represents a considerable height and width across the mouth of the horn in spite of the fact that the two sides taper down to a narrow opening at the transmission line end. However, 61 mc is a fairly low frequency for which to be using a horn antenna. In the UHF band the dimensions would be reduced

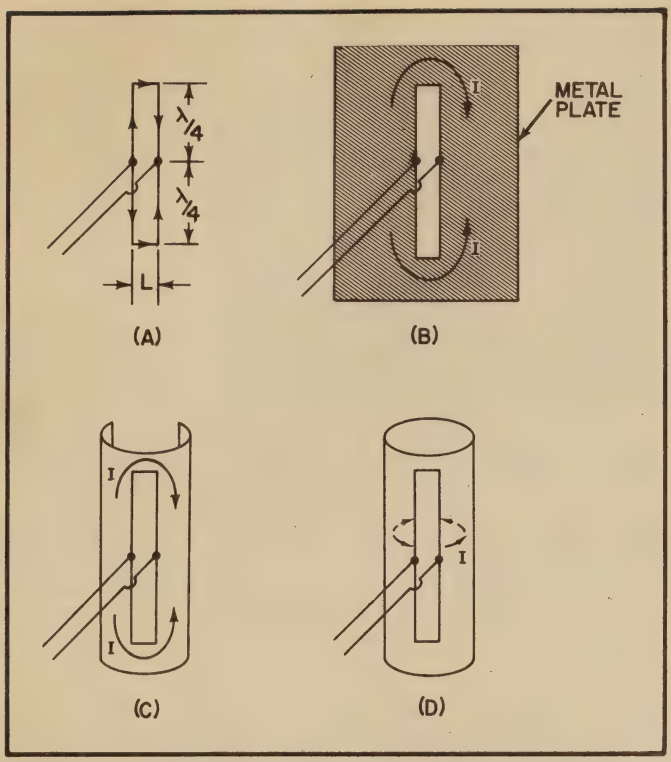


Figure 36. The Evolution of a Slotted Cylinder Antenna. (Courtesy Radio News)

considerably, for at 500 mc, they become about 1 foot by 1 foot across the mouth of the horn.

In an 8 foot model built, the power gain of this array over a half-wave dipole at 61 mc was slightly more than 1 db. See Fig. 34. Note, however, how the db figure rises with frequency and at 216 mc it was greater than 14 db. The gain thus is seen to be considerable and it also possesses the desirable characteristic of rising with frequency. In addition, this array possesses a fairly sharp directive pattern as shown in Fig. 35. Reception of signals from the rear of the structure is of the order of 1 percent.

Examination of the gain curves in Fig. 34 reveals how rapidly the gain decreases as the cut-off frequency is approached. This type of behavior is typical of horn type structures and it means that if appreciable gain is desired at a certain frequency and beyond, that the cut-off frequency be chosen well below this point.

The gain of a horn is also dependent upon the flare angle of the horn. This is the angle θ (in Fig. 33) which the horn sides make with each other as they approach the apex where the transmission line is located. Flare angles between 40° and 60° are most common. For each length of a side there is one angle which will give best results. In general, as the length increases, the optimum angle needed becomes smaller. In the 8-foot horn discussed above, a 60 degree flare angle was employed. This is a good compromise for the $\frac{1}{2}\lambda$ dimensions given in the formulas.

OTHER ANTENNAS

It would be difficult to attempt to describe all of the queer shapes and configurations which UHF antennas can take. However, before we leave this subject, it may be of interest to describe briefly several additional antennas which have been used for UHF reception.

A. Slot Antenna.* When two resonant quarter wave stubs are connected as shown in Fig. 36A to the end of a transmission line, and power is fed to these stubs by the line, very little radiated signal is obtained. This is due to the fact that currents of opposite phase flow in the stubs (as indicated by the arrows) and their fields effectively cancel each other. Only in the small end sections (labeled L) are currents in phase with each other and these radiate. However, the length of these end wires is small and very little effective radiated power is obtained.

It has been found, however, that if a half-wave slot is cut out of a metal sheet, as shown in Fig. 36B, that the non-cancelling currents in the L ends of the slot circulate about the entire plate and now we have a fairly efficient radiator. With a vertical slot we get a horizontally polarized wave. Since television has standardized on horizontal polarization, a vertical slot would be required.

By bending the plate into the form of a cylinder, the impedance of the path around the circumference of the cylinder will be sufficiently low so that most of the current will flow in this path. See Fig. 36D. This will give rise to a response pattern which is non-directional. While the discussion has centered about the slot as a radiator, identical results will be obtained when it is employed as a receiving antenna.

The impedance across the center of the slot is on the order of 500 ohms. This gradually decreases to zero at either end. Hence to properly match a 300-ohm twin lead line to the slot, it would have to be attached to points slightly off-center. An unbalanced coaxial cable can also be attached to the slot by connecting the center wire to one edge of the slot and the outer conductor to the other edge. The outer conductor may be bonded to the metal sheet, if desired.

* "ANTENNAS" by John D. Kraus. Published by the McGraw-Hill Book Company, New York.

Figure 37. A Commercial Slot Antenna. (Courtesy RCA)

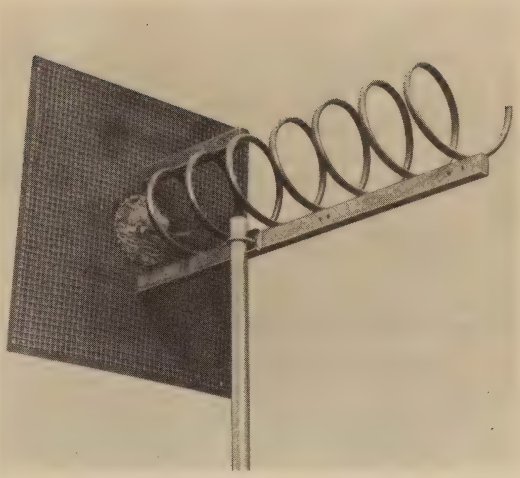


Figure 38. A Helical Antenna. (Courtesy Radio News)

A commercial slot antenna is shown in Fig. 37.

B. Helical Antennas. The helical antenna, shown in Fig. 38, may be looked upon as a form of loop antenna. In fact, Kraus points out that it is related to the straight wire (or linear) antenna on the one hand and to the loop antenna on the other. If the helical antenna were employed for signal transmission, the energy fed in at one end would be "fired" out at the other end. This is shown by the radiation pattern in Fig. 39. The energy is brought to the antenna by a coaxial cable, with the center conductor connecting to the end of the coiled helix and the outer conductor attaching to a reflecting screen. For reception the same type of response curve obtains.

Helical antennas can also be center fed with a balanced transmission line, and now the radiation pattern extends in more than one direction. As might be expected, the number of turns in the helix, the distance between turns (i.e., the pitch of the helix) and the circumference of each turn all will affect the response pattern of the array. In general, increasing the number of turns causes the beam width to become narrower; increasing the pitch or increasing the turn circumference will have the same effect, within limits.

The radiation pattern for a helical antenna shown in Fig. 39 holds true when the circumference of the helix turns are on the order of 1 wavelength at the operating frequency. If the helical antenna becomes small and compressed, the radiation pattern closely approaches that of a half-wave dipole. This latter application is not desired for TV reception.

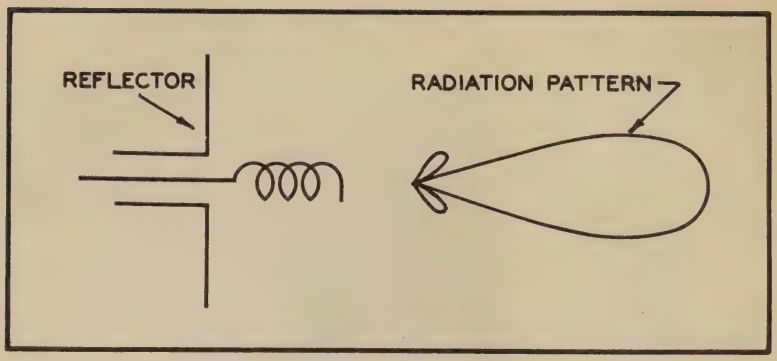


Figure 39. The Radiation Pattern of a Helical Antenna.

The helical antenna has a broad band characteristic, enabling it to be used over a 2 to 1 frequency range. By the same token, the input impedance remains fairly constant over the same range.

It might be of interest to note in passing that when the helical antenna is used for transmitting, that it radiates a circularly polarized wave. Now most technicians are familiar with vertically polarized waves and horizontally polarized waves. In the former the electric lines of force extend up and down and in the latter they extend in a horizontal direction, or from side to side. In a circularly polarized wave, electric lines of force may be considered as existing vertically, horizontally, and at all angles in between. This can be readily demonstrated by taking a dipole antenna, holding it in front of a transmitting helical antenna, and then slowly rotating the dipole. The amount of signal picked up will remain constant as the dipole is rotated through a complete revolution of 360°. In contrast, a vertically polarized wave will be picked up best by a vertical antenna and a horizontally polarized signal will be received best by a horizontal antenna.

For reception, a helical antenna will receive any signal, no matter what its polarization.* This is frequently advantageous because while television signals are radiated with horizontal polarization, this may change before the antenna is reached. A strictly horizontal or vertically polarized antenna might therefore not adequately receive all the available signal. A helical antenna, however, will.

COMBINATION UHF-VHF ANTENNAS

A problem that will soon be facing many TV set owners and TV service men will be that of choosing the UHF antenna best suited to their location and station frequency. In areas where only UHF

* There are several exceptions to this but they are not of interest in commercial television.

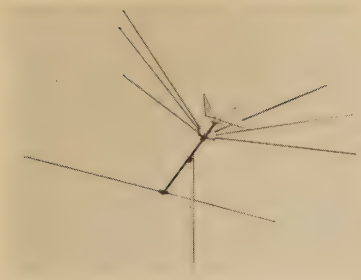


Figure 40. A Combination VHF - UHF Television Antenna.

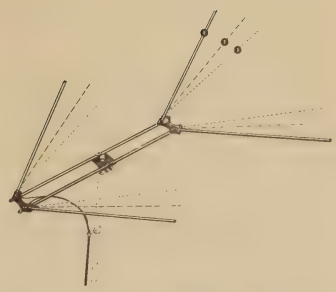


Figure 41. The Ward "U-Vee" Combination VHF - UHF Array.

stations are assigned, the choice will be between the various UHF antennas available. But in many parts of the country, there will be both UHF and VHF signals and for these locations the following choice will exist.

1. To use one all-VHF antenna and one UHF antenna, each with its own lead-in line.

2. Or, to use a combination VHF-UHF array possessing a single lead-in.

Choice No. 1 is the more flexible of the two and generally will provide the set with the stronger signals. Whenever you combine two arrays possessing widely differing responses, a certain amount of loss will be occasioned by both sections. If the combination antenna stems from the basic "V" array, then the angle of the antenna rods which is best for VHF reception will not be best for UHF reception. By the same token, the best adjustment for UHF reception is not the most desirable for VHF signals. And, as is most common, when you choose a compromise position, then reception in both regions suffer.

If the combination array is of the type shown in Fig. 40, some sort of decoupling network must be inserted between the UHF and the VHF elements. In essence, what we are principally trying to do with this decoupling or filter network is to prevent the VHF assembly from affecting UHF response. (The UHF antenna will usually have little effect on the VHF response and for most practical purposes may be disregarded.) Signals passing through the decoupling network will suffer some attenuation, and in this respect, less than optimum operation will be obtained.

On the other hand, in strong and medium signal areas whatever loss is occasioned by combining VHF and UHF elements will have little noticeable effect on the picture. Furthermore, combination arrays will be more economical, both from the standpoint of initial

cost and of subsequent installation and cost is a very potent factor in sales.

The consensus of opinion among antenna engineers is that while better results are obtainable generally from separate VHF and UHF arrays, a substantial market will exist for combination arrays and these will be manufactured in quantity.

The opening of the UHF band has only just begun and the number of combination arrays is still quite limited. Many manufacturers, when asked about their plans, indicated a "wait-and-see" attitude. However, several combination arrays have already been marketed and it may be of interest to examine these to see what form they take and how they operate.

J.F.D. Jetenna 283. J.F.D. has recently announced an array to operate over all VHF and UHF channels. Shown in Fig. 40, it is seen to consist of a low band conical for VHF signals and a broad band triangular (or fan) dipole for UHF signals. A single lead-in line delivers signals to the receiver through the use of a special coupling device which is mounted directly at the antenna itself.

By virtue of the positioning of the various elements, the active rods of the VHF array will serve as reflectors for the UHF dipole. The VHF elements, in turn, will possess their own reflector. A gain close to 9 db will be available from the VHF section while the UHF section gain will be on the order of 4 db. The UHF plates are stamped of aluminum, with a tip to tip length of 16 inches. This will permit matching of the array to a 300-ohm line. Finally, the two triangular plates of the UHF array will have a forward inception angle of 35° to match the forward inclination of the VHF elements.

Vertical directivity of this UHF array is quite broad but the horizontal directivity, with the reflector elements, is good. For local areas surrounding a UHF broadcast station where ground reflected signals is low, good results may be obtained with this array.

"V" Type Combination Antennas. The ability of a "V" type of antenna to receive VHF and UHF signals was briefly mentioned in the first section of this text. Several antenna companies have taken advantage of this property to devise modified "V" antennas which will operate over all channels with good gain.

The modified array which all have adopted in one form or another is shown in Fig. 41. Basically the array consists of four rods; two at the front and two at the rear. The lead-in line to the receiver (300-ohm twin lead) connects to the two rear rods. Comparing this arrangement with arrays we are familiar with, the only conclusion we can come to regarding the front two rods is that they serve here as directors. This they do. However, closer examination of the array indicates that unlike more conventional arrays, the two front rods are electrically connected to the two rear units. The purpose of these connecting rods is twofold.

First, the two rods serve as a transmission line to conduct whatever signal is picked up by the two front rods to the two rear rods. In addition, the two rear rods also pick up that portion of the signal which passed over the front rods and combine this with the energy received from the front rods via the transmission line. Obviously, to obtain maximum results from this combination, the length of the connecting rods must be carefully chosen. Signal pick-up from the rear of the array is low because the energy which approaches the array from the rear and captured by the front and rear rods combine out-of-phase and are therefore cancelled out.

The second purpose of the connecting rods is to support both front and rear dipoles and produce a mechanically sturdy array.

It is characteristic of "V" type antennas that the longer each side of the "V" becomes as compared to the operating frequency of the signal, the narrower must the angle between the sides be made for an optimum high-gain single-lobe pattern. Thus, if we use the same "V" for operation on the low and high-band VHF and for the UHF region, then the angle to which the bars must be set depends upon the conditions in your locality.

In position No. 1, Fig. 41, reception is best on the VHF band. The included angle between the rods is 90°. The manufacturer also suggests application of this antenna with the 90° angle for scattered UHF stations in a metropolitan area. In such strong signal UHF service areas a careful check at the time of antenna installation can determine a fixed position for the 90° array that will allow good reception on all nearby UHF channels together with both near and distant VHF channels.

In position No. 2, Fig. 41, the included angle is set at 60°. Reception is divided between VHF and UHF channels, with the highest UHF channels suffering the most due to lobe break up.

In the final position, No. 3, Fig. 41, the included angle between the dipole rods is 45° and now best reception is obtained on the UHF channels, especially those located above 750 mc. VHF reception in this position is below normal and likely to be unsatisfactory except in strong VHF signal areas.

A comparison of the response curves and the antenna gain for each of the three positions is given in Fig. 42. Note in all instances how much better this array performs as the frequency rises. This is an especially desirable characteristic for UHF reception.

The U-Vee antenna, as this array is called by its manufacturer (The Ward Products Company) can be obtained stacked for improved reception. (JFD produces a similar antenna but calls it the ULTRA V-BEAM. See Fig. 43. Its rods also have provision for altering the included angle to suit the frequency or frequencies of the stations to be received.)

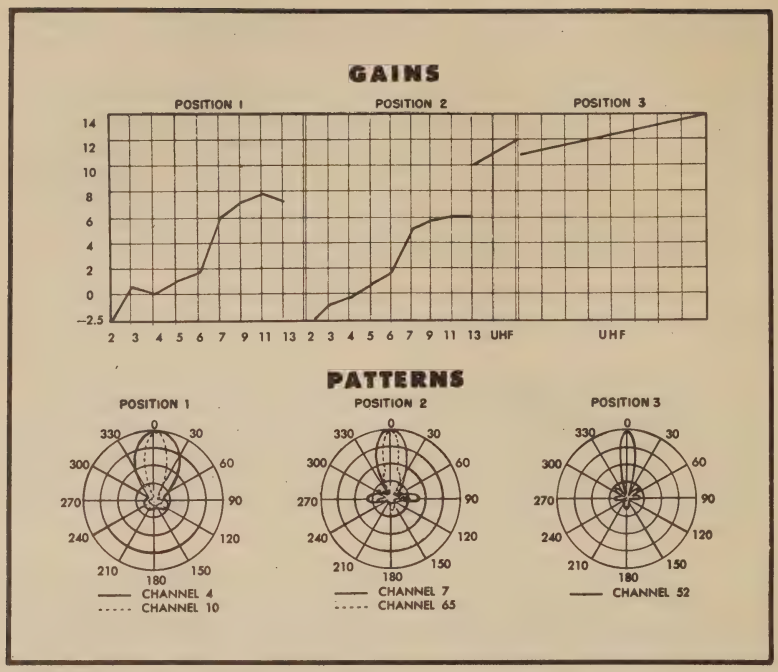


Figure 42. A Comparison of the Response Curves and Gain of the "U-Vee" Antenna for the Three Element Positions Shown in Figure 41. (Courtesy Radio News)

Ward Products has a variation of the "V" antenna which it calls the Trombone. See Fig. 44. Use of this antenna on the UHF channels is similar but not identical in principle to the U-Vee array. The 90^{O} angle for all four vees that gives best fringe-area performance on both VHF bands will produce multiple lobes over the UHF range. This can still be useful in the primary service area of the

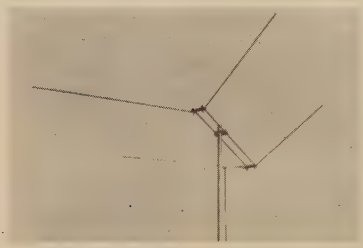


Figure 43. The JFD "ULTRA V-BEAM" Combination Array.

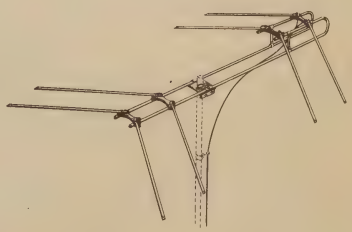


Figure 44. The Ward "Trombone VHF - UHF Array. (Courtesy Radio News)

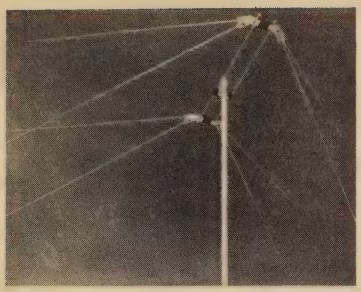


Figure 45. The RMS Combination Array. (Courtesy Radio News)

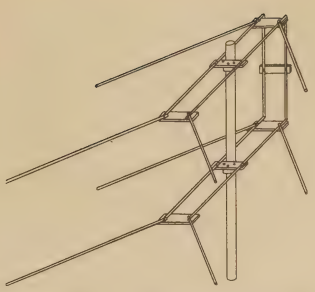


Figure 46. A Modified "V" Array Stacked Two High. (Courtesy TACO)

UHF stations but it will prove unsatisfactory in weak signal areas or where there are multiple reflections.

According to the manufacturer, the Trombone is not peaked for a single lobe over the UHF band by using the 60° angle (mid-position) for all four vees. This arrangement gives highest gain on only the lowest UHF channels (near 500 megacycles) and reduces the gain in the VHF band. A better choice for good low-channel Trombone performance is to set only the forward pair of vees to 60°, leaving the back pair (on the Trombone loop) at 90°. When the high end of the UHF band comes into use, above channel 62, the forward pair of vees can be set at 45° included angle for top performance there with minimum reduction in VHF gain.

The best choice for the majority of the UHF channels is to set the three forward vees to 60° and the back vee at 90° (widest angle). This gives optimum gain at UHF, with a partially-split forward lobe that is said to allow considerable latitude in lining up different UHF stations, but still giving a good front-to-back ratio and minimum side lobes for ghost rejection. Performance on the VHF channels is still good, with a fairly narrow main lobe and good front-to-back rejection.

Variations of the basic "V" are endless and it may be expected that different manufacturers will put other twists in it. The RMS array is shown in Fig. 45 and it is seen to possess two rods at each point where the "V" of Fig. 41 uses one. Stacking of the vees is shown in Fig. 46. "Q" bars are used to connect the upper and lower stacks and are so designed to raise the apparent impedance of each section so that the antenna will work effectively into a 300-ohm load.

The "ULTRA Q-TEE" antenna, Fig. 47, is another combination VHF-UHF array that possesses a number of features which differ from the other combination antennas that we have just discussed. The UHF portion of this array consists of the two foremost rods

Figure 47. The "ULTRA Q-Tee Antenna. (Courtesy La-Pointe Plascomold)

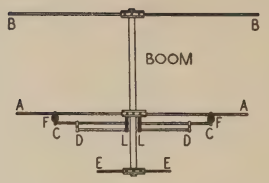


Figure 48. The VHF Portion of the "ULTRA Q-Vee" Antenna of Figure 47. (Courtesy Radio News)

that are tilted forward. The straight rod just behind it serves as the reflector. The same straight rod also serves as a director on the upper VHF band for the array of rods that are positioned behind it. These other rods form the VHF section of this array.

In order to understand the reason for using this particular form of antenna, let us first consider the VHF section. This is shown in Fig. 48. Dipole A is cut for a half-wavelength at 63 mc (channel 3) and this rod is designed to receive all of the low band channels (2-6). Rod B is the reflector for dipole A and its length is somewhat greater than A's.

Dipole C-C is cut for a full wave at the center of the high VHF band. F-F are printed circuit isolation filters, resonant at 195 mc and designed to isolate the low-channel dipole (A-A) from the high channel dipole (C-C). Rod D-D, a matching and phasing section, performs a dual function and accounts for the operational characteristic of this antenna. In the high VHF channels elements D-D are "T" match sections which tap the dipole (C-C) and provide a 300-ohm termination at (L-L). The high channel antenna is, therefore, a full wave antenna "T"-matched, with a half-wave director (E-E).

On the low channels the isolation filters (F-F) have a low inductive impedance since they operate below their resonant frequency. The high channel dipole (C-C), combined with element (D-D) form a double "T" matching section which taps dipole (A-A) to again provide a 300-ohm termination at (L-L).

The close positioning of A-A, C-C, and D-D form an array possessing a very low "Q". This low "Q" in effect represents a dipole of a large electrical diameter and which, in turn, accounts for the broad (all VHF channel) frequency characteristics of the array.

So much for the VHF sections of the composite array of Fig. 47. To this is added the tilted dipole in front of rod E-E for reception

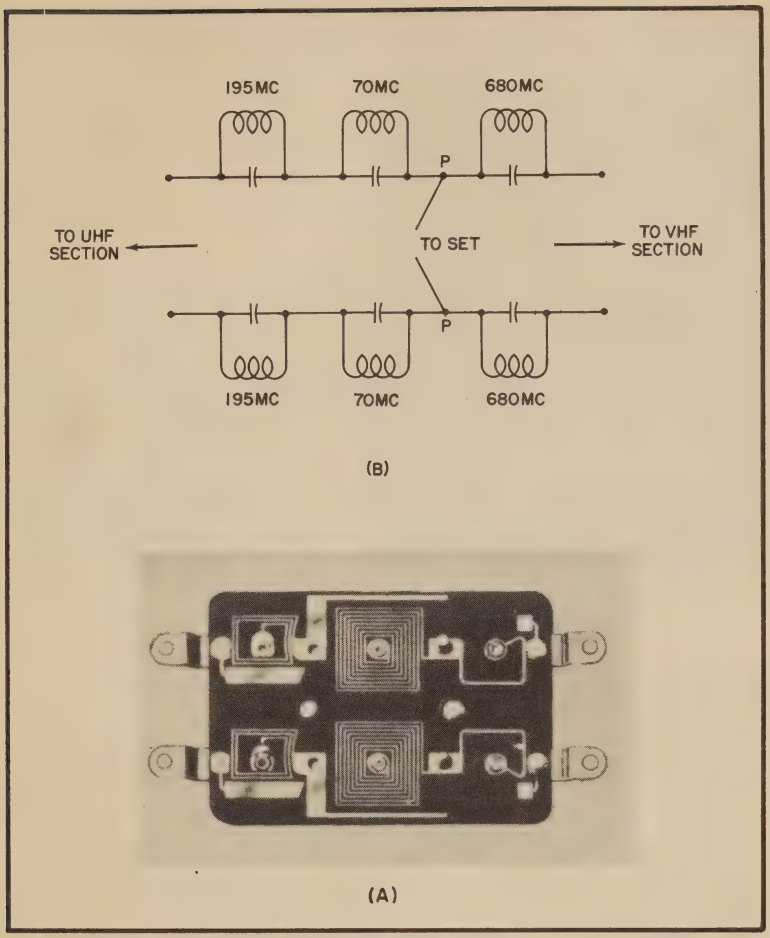


Figure 49. (A) Physical Appearance of VHF - UHF Separation Filter Used in "ULTRA Q-Tee" Antenna. (B) Low-frequency Equivalent Circuit of Filter. (Courtesy Radio News)

of signals over the UHF band. E-E, as we have said, acts as its reflector.

Now, to prevent interaction between VHF and UHF sections, another printed circuit filter is added to the array. The low-frequency electrical equivalent of this filter is shown in Fig. 49B, while its physical appearance is indicated in Fig. 49A. The transmission line to the set is connected across points P-P. The UHF antenna is then connected to one end of this filter and the VHF section to the other. The various resonant circuits comprising this filter are

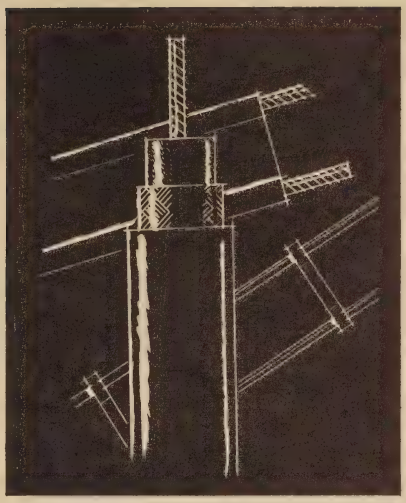
shown, together with their resonant frequencies. Isolation, now, is achieved in the following manner. UHF signals leaving the UHF array see short circuits in the 195 mc and 70 mc resonant circuits because the UHF signals can pass through the capacitors of these sections. On the other hand, UHF signals see high impedances in the 680-mc tuned circuits. Therefore, there is no tendency for any UHF signal picked up by the VHF antenna to reach points P-P. Any UHF voltages reaching the transmission line must thus come from the UHF antenna.

Considering VHF signals, those coming from the VHF section will encounter little opposition from the 680-mc resonant filters and therefore VHF signals will reach points P-P undiminished. However, VHF signals picked up by the UHF array will be largely lost across either the 70 mc tuned circuits (for low VHF band signals) or the 195-mc filters (for high VHF band signals). Very little of VHF signals from this source will reach points P-P.

The antenna is designed to operate with any 300-ohm balanced line and at present this means either the 300-ohm flat twin lead or the 300-ohm tubular. There are, however, other low-loss lines being developed to provide better UHF operation than the lines now available.

SECTION 2

TRANSMISSION LINES AND MATCHING NETWORKS



TRANSMISSION LINES

Transmission lines in common use at VHF frequencies include a 450-ohm open-wire line, 300-ohm flat and tubular lines, and two coaxial cables, the RG-59U and RG-11U. See Fig. 50. At 100 mc, the signal loss per 100 feet of the open wire line is .35 db, in the 300-ohm lines it is about 1.2 db, in the RG-11U cable it is 1.8 db, and in RG-59U it is 3.8 db. The open wire line has, by far, the lowest attenuation and, as such, is eminently suited for fringe area installations. Unfortunately, this line is the most difficult one to work with physically and for that reason is not used more widely. Its 450-ohm impedance is somewhat of a hindrance, too, since most antennas and receivers are designed for 300 ohms. However, this is not as serious as you might at first believe. There are practically no television receivers whose input impedance remains constant at 300 ohms for all channels. (The same is true of your so-called 300-ohm twin lead or your 300-ohm antennas). Thus, simply connecting the 450-ohm line to the receiver will frequently (although not always) give you as good results as you would obtain by carefully matching the line to an impedance transformer and then making the connection to the receiver. (Obviously, in these instances, the line and the receiver input impedances are matching. If there was a mis-match then an impedance transformer would help.)

Recently, a 375-ohm open-wire line was announced. This brings the line impedance closer in value to the standard 300-ohm receiver input and it is doubtful whether a matching network will ever be required with this line.

The 300-ohm line (flat) is the one which is most extensively employed at VHF because it is economical, it matches receiver input impedances directly and its attenuation is still low. In areas where the surrounding noise is high, use of the unshielded open-wire or 300-ohm lines becomes impractical and one of the coaxial cables must be employed.

With increase in frequency, line db attenuation rises, too. Thus, at 500 mc, the open-wire loss mounts to .78 db, the 300-ohm line loss becomes 3.2 db, RG-11U attenuation increases to 5.0 db and RG-59U loss reaches the rather high figure of 9.4 db.

Comparative figures at 500 mc and 1000 mc are given in Table 1 and it can well be appreciated how carefully the amount of line needed must be figured in order that no more than necessary be employed.

TABLE 1
TRANSMISSION LINE LOSS
DB LOSS PER 100 FEET

TYPE	100 MC		500 MC		1000 MC	
	WET	DRY	WET	DRY	WET	DRY
450 ohm open wire*	***	0.35	***	.78	***	1.1
300 ohm tubular	2.5	1.1	6.8	3.0	10.0	4.6
300 ohm flat	7.3	1.2	20.0	3.2	30.0	5.0
RG-59U	***	3.8	***	9.4	***	14.2
RG-11U	***	1.8	***	5.0	***	7.6

*Estimated values - unknown for wet conditions.

An interesting sidelight on line attenuation is the rapid rise in this value in unshielded lines when they become wet. The 300-ohm flat line appears to be most vulnerable in this respect, jumping from a value of 3.2 db (at 500 mc) when the line is dry to 20.0 db when it becomes wet. What this rise would do even to a strong signal is quite obvious. The 300-ohm tubular is considerably better and hence would be more desirable for installation purposes. No data is available on the attenuation increase in wet open-wire lines although it is not considered to be appreciable. Shielded cables, such as the RG-11U and RG-59U, are not affected at all by inclement weather.

An important factor in keeping overall attenuation down is the careful routing of the line from antenna to receiver. This is especially true in the case of unshielded lines. Keep the line away from gutters, pipes or other metal objects as much as possible. Avoid sharp bends in the line. If a bend must be made, have it occur gradually. Finally, secure the line tightly by means of stand-

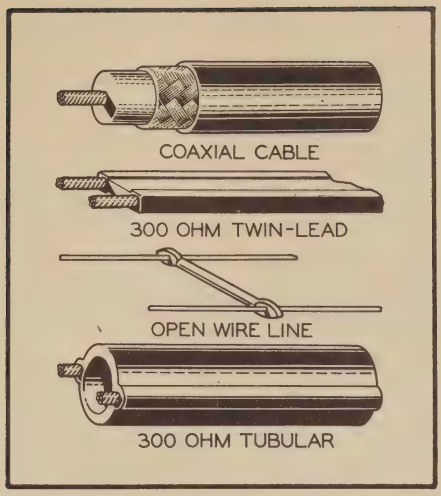


Figure 50. Transmission Lines in Common Use for Television Reception.

off insulators so that it does not sway in the wind or otherwise alter its position.

Also to be carefully avoided are patched lines. It is better to have too much line than to find that you do not have enough and therefore have to patch on an extra section in order to reach the set. Patched lines almost always lead to increased line attenuation, sometimes by as much as 2 db or more.

Impedance Matching. While it is frequently unnecessary to match carefully 450-ohm impedances to 300-ohm impedances, the same is not true when a 75-ohm impedance is to be connected to a 300-ohm impedance. Here a careful match should be made because of the great disparity between the two values and also because 300-ohm impedances are usually balanced while 75-ohm impedances are not.

The basis for most matching devices is the behavior of quarter-wave and half-wave sections of transmission lines. It has been found that when one end of the quarter-wave section of transmission line is left open, that any electrical circuit connected across the other end will see a short circuit. We are assuming, of course, that the transmission line section is cut to a quarter-wave length at the frequency at which it is to be used.

By the same token, if one end of the line is short-circuited, then a very large impedance will appear across the opposite end. This high impedance will exist at only one frequency, this being the one

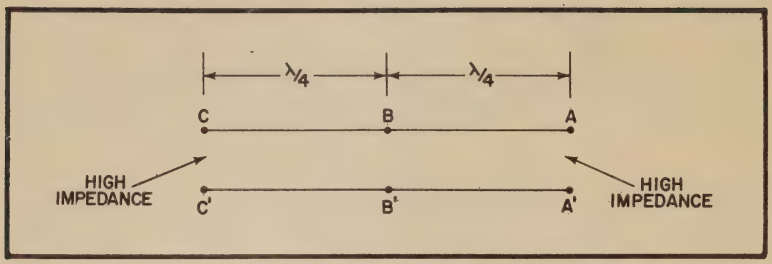


Figure 51. A Half-wave Line May be Considered as a Combination of Two Quarter-wave Lines.

for which the line is cut. At all other values above and below this frequency, the impedance will fall off.

An outgrowth of this behavior of a quarter-wave line is its ability to match two widely different impedances. For example, instead of short-circuiting one end of a quarter-wave line, suppose we connect the terminals of a dipole antenna across here. The impedance of the antenna is approximately 75 ohms. Then the impedance that we will see at the other end of the quarter wave line will be given by the formula:

$$Z_m = \sqrt{Z_{in} \times Z_{out}}$$

where

Z_m = impedance of $\lambda/4$ matching section

Z_{in} = impedance of circuit connected across one end of the matching section.

Z_{out} = impedance developed at opposite end of the matching section.

To illustrate the use of this formula, suppose it is desired to match a 300-ohm line to a 75-ohm dipole. In this case, Z_{in} = 75 ohms, Z_{out} = 300 ohms, and Z_m is to be found.

$$Z_m = \sqrt{75 \times 300}$$

$$= \sqrt{22500}$$

$$= 150 \text{ ohms}$$

Thus, we take a section of a transmission line having a characteristic impedance of 150 ohms, and cut a quarter-wave section from it. Then, we connect one end to the antenna and attach the other end to the 300-ohm line leading to the receiver. The system now is matched and maximum power will be transferred from the antenna to the receiver.

A half-wave line may be considered as a combination of two quarter-wave lines. Thus, in Fig. 51, if end A-A^1 is open, then a quarter wavelength away, at B-B^1, an effective short-circuit will exist. Travelling an additional quarter wavelength along the line, to C-C^1, we see a high impedance (i.e., open circuit) because of the low impedance present at B-B^1. A half-wave section presents at its output terminals the same impedance existing across its input terminals. A half-wave line thus produces a 1 to 1 impedance transformer action.

A solution for achieving a match between two transmission lines of different impedance which is sometimes employed was shown in Fig. 19. Here one line has an impedance of 450 ohms and the other has an impedance of 300 ohms. By removing some of the spacers in the 450-ohm line and gradually tapering the wires in, a smooth impedance change can be effected. As mentioned previously, the tapered section should extend at least over a distance of 2 wavelengths. If a small amount of mismatch is tolerable, the taper length may be reduced to perhaps one-half wavelength.

What we are doing here is to gradually transform the impedance of the 450-ohm line to a 300-ohm value. We could just as well have kept line A as it was and tapered line B out. In the present illustration it was easier to taper line A and so this was done.

Matching Balanced to Unbalanced Lines. There is frequently occasion to match balanced to unbalanced transmission lines. Simply connecting a balanced line to the inner and outer conductors of a coaxial cable would not effect a match--even if the characteristic impedances of the two lines were equal--because currents from the balanced line would tend to flow along the outer surface of the coaxial line, resulting in a considerable loss of radiated energy.* To connect the two lines, without permitting the currents to stray from the desired paths, a special converter known as a balun must be employed. (Balun is the contracted name for a balanced-to-unbalanced line converter. The "bal" of balanced and the "un" of unbalanced are combined to form the new word. For the balun of Fig. 52, the alternate name of bazooka is sometimes used.)

A coaxial cable and a balanced twin-lead transmission line can be matched as shown in Fig. 52A. In the balanced line, each conductor possesses the same potential and the same impedance to ground; which is why the line is said to be balanced. In the coaxial line, the outside surface of the outer conductor is at ground potential while the R.F. voltages and currents are confined to the inner surface of the outer conductor and to the line running through the center of the cable. The purpose of the balun is to prevent any of

* In parallel wire lines, the currents in the two wires flow in opposite directions and are close enough together so that the radiation effects cancel out.

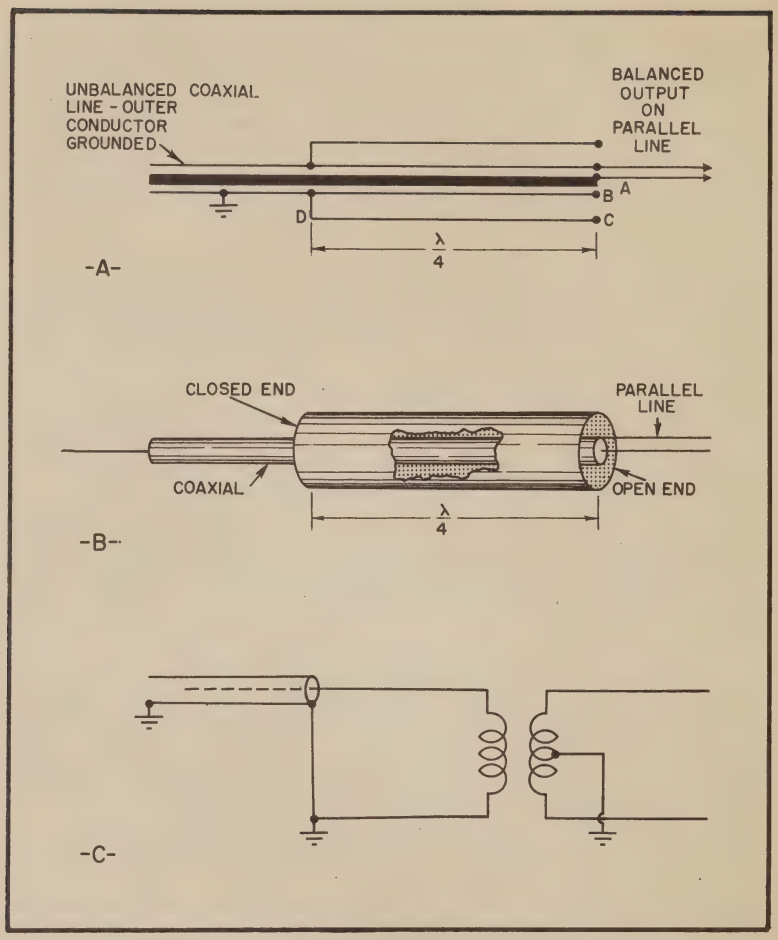


Figure 52. (A) Bazooka (or Balun) Formation. (B) Physical Appearance of Balun. (C) Equivalent Low-frequency Circuit of Matching Device.

the R.F. energy passing between the coaxial cable and the balanced line from reaching the outer surface of the coaxial cable. It accomplishes this by presenting a high impedance, at the point of connection, to any currents desiring to reach the outer surface of the cable. Here is how this high impedance is formed.

A shield is placed around the outer conductor of the coaxial line and is connected to the outer conductor at a point one quarter-wave from the end of the line where the balanced line is to be attached. Now this second shield and the outer conductor form a quarter-

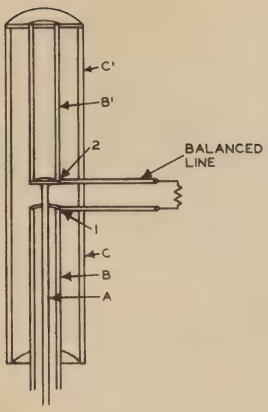


Figure 53. A Modification of the Balun of Figure 52. This Unit Possesses Better Electrical Balance over a Range of Frequencies.

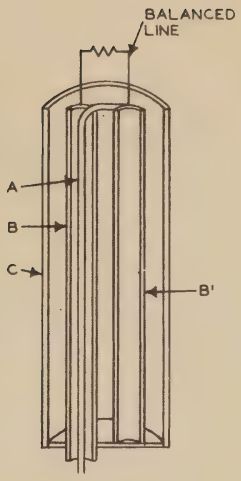


Figure 54. A Compact Version of the Balun of Figure 53.

wave section. Since the end of this section, at point D, is grounded, the other end presents a high impedance between points B and C. Any currents desiring to flow from the balanced line to the outer surface of the coaxial cable encounters this high impedance and is thereby prevented from doing so. The inner conductor is unaffected by this second shield and retains the impedance it previously possessed. The balun isolates point B from ground even though the outer conductor of the coaxial cable is grounded at one or more points below point D. See Fig. 52B.

The equivalent low-frequency circuit of the balun is shown in Fig. 52C and is seen to be similar to a transformer in which one side of the primary and the center-tap of the secondary are grounded. Insertion of the balun has not affected the impedance of either line and the characteristic impedance of the cable should be chosen to equal that of the balanced line. If the balun is employed at frequencies other than that for which the distance B-C is not one quarter-wave, then the impedance between points A and B will not be high, resulting in an unbalance with resultant loss of power due to standing waves and radiation.

To overcome the limitation of narrow band width which is characteristic of the foregoing balun, the modified balun shown in Fig. 53 was devised. This is similar to the previous unit except that an additional coaxial section B^1, C^1 has been added. This section has the same impedance and characteristics as the section formed by B and C of the balun. This means that whatever impedance is presented to the incoming balanced line between point 1 and ground due

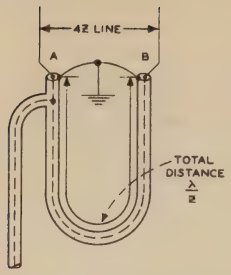


Figure 55. Another Method of Connecting a Coaxial Line to a Balanced Line.

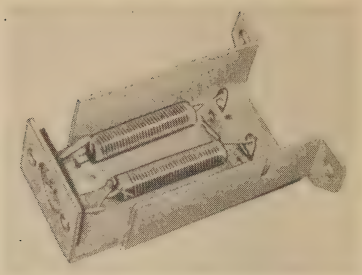


Figure 56. An Elevator Matching Transformer Employed in VHF Receiver. (Courtesy RCA)

to section B and A will be exactly equal to the impedance developed between point 2 and ground, due to section B^1, C^1. This will be true at all frequencies, enabling the incoming balanced line to remain undisturbed.

It is possible to reduce the physical dimensions of this balun in half by folding the upper section back on the lower section. See Fig. 54. This compact unit, at UHF frequencies, will seldom exceed 5 inches in length.

Another method of connecting a coaxial cable to a balanced line is shown in Figure 55. The end of a coaxial cable is folded back on itself for a half wavelength in such a manner that the inner conductor at each end may be connected to a balanced line. The ends of the inner conductor are points A and B in Figure 55. Since these two points are separated from each other by a half wavelength, the amplitude of their voltages (with respect to ground) will be equal but 180° out-of-phase. This is the proper condition for a balanced line.

The impedance presented across points A-B is four times the impedance of the coaxial cable. The reason for this is as follows: The voltage between point A and ground is equal to the voltage between point B and ground. Therefore, the total voltage between points A and B is 2E or twice the voltage carried by either coaxial cable alone. Now, the power obtained across points A and B must equal the power fed in by the single coaxial cable. Thus

$$P_{in} = P_{out}$$

But, P_{in} is equal to

$$P_{in} = \frac{E^2}{Z_1}$$

where Z_1 is the impedance of the coaxial line. By the same reasoning, P_{out} is equal to

$$P = \frac{(2E)^2}{Z_2} = \frac{4E^2}{Z_2}$$

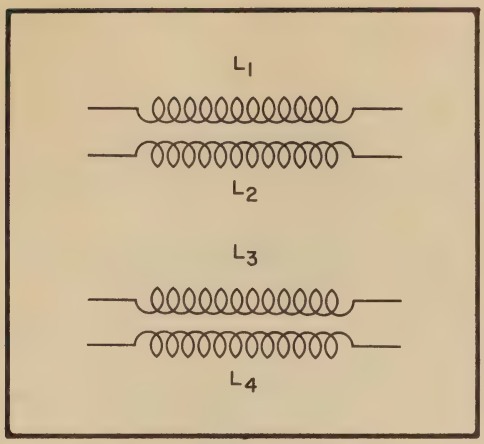


Figure 57. The Elevator Transformer of Figure 56 Consists of Two Sets of Coils. L_1 and L_2 Form One Set; L_3 and L_4 Form Another Set.

where Z_2 is the impedance between points A-B. Since the power has not changed, Z_2 must be equal to $4Z_1$ because only in this way can $P_{in} = P_{out}$. Thus,

$$P_{in} = P_{out}$$

Substituting for each, we have

$$\frac{E^2}{Z_1} = \frac{4E^2}{Z_2}$$

or

$$Z_2 = 4Z_1$$

Elevator Transformer. There is still another way whereby different impedances may be matched and this is by an arrangement known as an elevator transformer. The unit first appeared in VHF receivers and possesses the form shown in Fig. 56. Its purpose here was to match the receiver input circuit (which has an impedance of 300 ohms) to either a 300-ohm twin lead or a 75-ohm coaxial cable.

The elevator transformer consists of two sets of coils as shown in Fig. 57. One set of coils (L_1 and L_2) are closely wound on one form and the second set of coils (L_3 and L_4) are placed on another form. Electrically, each set of coils can be considered as a transmission line having a characteristic impedance of 150 ohms and a length of approximately one-quarter wave at the lowest operating frequency.

Now, if it is desired to match a 75 ohm line to one end and a 300-ohm input circuit impedance to the other end, we would connect

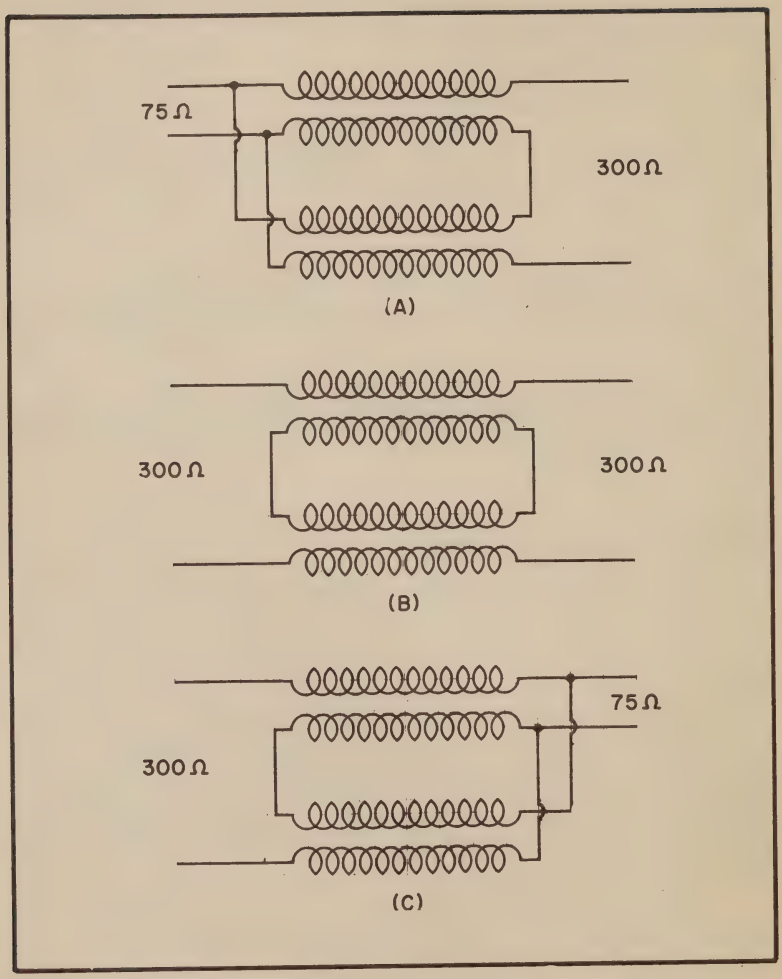


Figure 58. Various Impedance Combinations Obtainable with the Elevator Transformer.

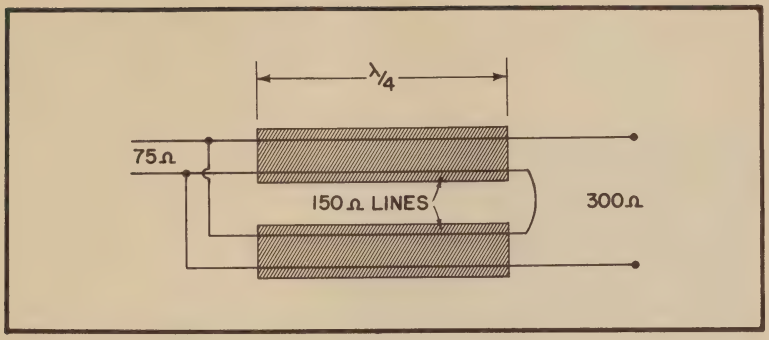


Figure 59. An Elevator Transformer Using Transmission Lines. This Device is Widely Used at UHF.

the two sets of coils as shown in Fig. 58A. At the 75 ohm end the two coils are connected in parallel. Thus, two 150-ohm impedances in parallel produce a resultant impedance of 75 ohms.

At the other end of the coils, they are connected in series, producing the necessary 300 ohms.

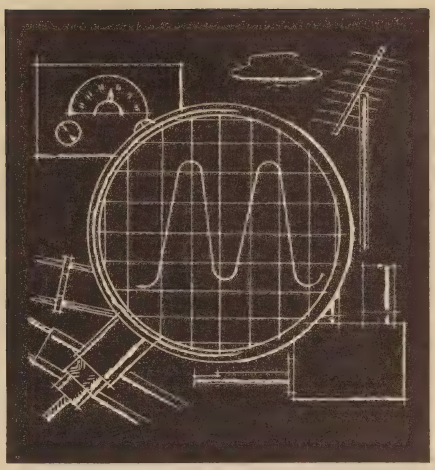
If there are 300-ohms at both ends, the coil arrangement would be as shown in Fig. 58B. Now both ends are connected in series. Finally, a 300-ohm line can be matched to a set having a 75-ohm impedance as shown in Fig. 58C. Now, it is the input ends of the lines that are connected in series and the output ends that are in parallel. The impedance at one end can be balanced while it is unbalanced at the other end and the match is still effective. Or both ends can be balanced or unbalanced, as desired.

The elevator transformer, although developed for VHF receiver application can be adapted to UHF.

While the elevator transformer uses coils that function as transmission lines, it is perfectly possible to achieve the same results using suitable transmission lines. Fig. 59 illustrates how two quarter-wave sections of 150-ohm twin lead line can be connected to match a 75-ohm impedance at one end to 300-ohms at the other. Following the above discussion, all the other combinations can be obtained as well.

SECTION 3

UHF INSTALLATION PRACTICES



UHF ANTENNA INSTALLATION

The job of locating the best location for the UHF antenna follows closely the present VHF practice of probing. That is, one man will remain at the receiver while a second man will take the antenna, with lead-in, to the roof. The lead-in is then run loosely from the antenna to the receiver following the most likely route of the final installation.

After the lead-in has been connected to both the probing antenna and to the receiver, the set is turned on. The controls should be adjusted so that a picture will be produced if a signal is received. Simultaneous work is now begun by the man on the roof with the unmounted antenna and by the man at the receiver. A two-way communications system enables them to talk with each other.

The man on the roof moves the antenna to various positions and the man at the receiver judges each position in terms of relative signal strength and picture quality. After all likely and accessible areas of the roof have been probed, the most promising locations are re-tested, until the best single location for the antenna is found.

Experience has shown that where the received signal is received directly from the transmitter, a certain amount of leeway in position is possible. This may permit the UHF array to be mounted on the same post holding up the VHF antenna. On the other hand, when

the signal is a reflected one, it has been found that position tends to be quite critical. In fact, in the short distance of only six inches, the signal intensity can fluctuate considerably. This applies to vertical placement as well as to horizontal position.

Keep lead-in lines from separate VHF and UHF antennas away from each other. Any undesirable UHF signals picked up by the VHF array can be transferred from the VHF lead-in line to the UHF lead-in line if the two lines come close enough to each other. Generally a six-inch separation will prevent this type of signal transfer.

In areas where there is no trouble from ghosts, choosing the best location for the UHF antenna can be quickly carried out using a field intensity meter. UHF meters are not yet available, but any of the VHF instruments which use a Standard Coil tuner can be adapted to UHF by simply replacing some of the unused VHF channel strips with appropriate UHF strips. Simpson and Approved Electronics field intensity meters fall in this category.

The type of antenna to use will depend to a large extent on the strength of the received signal and on the interference conditions existing at that location. Near the transmitter, a simple array such as the fan dipole may prove quite satisfactory. Farther out, a stacked "V", a parabola, or even a rhombic array might be required. These are capable of greater gain and sharper directivity, if this latter feature is required. In very weak signal areas, stacked dipoles, yagis, and stacked rhombics would probably bring in whatever signal is present.

In UHF installations, the admonition to raise the antenna as high as possible will generally pay off. That is, a definite signal increase with height is generally noticeable, although exceptions will be encountered from time to time. Of course, this must be tempered by the fact that the higher the antenna, the greater the amount of lead-in required and sometimes the increased lead loss can offset the stronger signal.

The increase in signal strength with height is not a smooth transition, but rather one that varies between minima and maxima. Thus, as you go up, the signal strength will rise, then decrease somewhat with further height, then rise again, etc. This variation is due to the fact that the signal present at the antenna is a combination of a direct ray and a ground reflected ray. Where these two rays combine in phase, signal strength is high; where they combine out of phase, signal strength is lowered.

You may also find a similar variation as you move the antenna horizontally although here the presence of buildings, towers, foliage, hills, etc., have a greater disturbing effect.

The rise in operating frequency brings with it additional effects aside from those already noted. For one thing, the ability of the

wave to pass around objects and obstacles in its path decreases as the size of these objects approach and exceed the wavelength of the passing signal. Thus, a high tower or a long chimney stack may appear inconsequential to frequencies of 50 mc or less, whereas to 550 mc waves, it may become quite formidable, and in many instances, unpassable. Also, at ultra-high frequencies it has been observed that the growth of leaves and other foliage in the spring and summer will often reduce the strength of otherwise strong signals. Sometimes, a usable picture in the winter will become completely unusable in the spring and summer. This point must be kept well in mind during fall and winter installations when foliage may be sparse or missing. In the summer, with the greenery in full bloom, signal areas found to be useful can be depended upon to maintain or even increase in signal intensity during the colder months of the year.

Along these same lines, marked decreases in signal strengths have been noted during heavy rains and violent snow storms. These are new concepts, both to the service man and the customer, but in time both will grow accustomed to these now-regarded strange effects. In the beginning, though, a considerable amount of customer explanation will be required.

The sensitiveness of short waves to small and moderately sized obstacles is further demonstrated when indoor UHF antennas are attempted. It has been found that these are generally unsatisfactory except in the strongest signal areas and even here, wide fluctuations in signal strengths have frequently been found to occur whenever anyone walked in front of the antenna. Where it is impossible to erect roof antennas, due to certain restrictions, then window-mounted arrays are next preferred. Only as a last resort should indoor antennas be attempted.

HOW TO CHECK ANTENNA SYSTEM MISMATCH*

In order to obtain the maximum signal from an antenna, it is necessary that the complete system be matched as far as possible. This means that the transmission line should match the antenna at one end and the receiver input at the other. If there are any impedance transformers within this system (either at the set or at the antenna) they must be matched, too.

Now, it is one thing to make such statements and quite another to carry them out. Ask the average service man how he would determine whether a line is matched and his answer is likely to be vague. Very few technicians take the trouble to check the mismatch on an installation. But with the advent of UHF, closer matching will be more important because it can mean the difference between a usable picture and one that is poor and unsatisfactory.

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* Based on an article by John A. Cornell in the September, 1949 issue of Radio & Television News Magazine, P. 52.

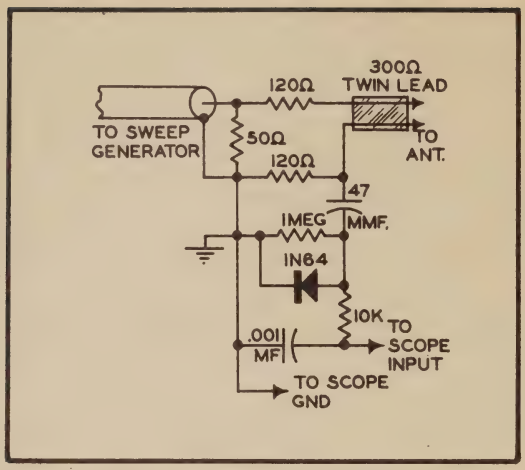


Figure 60. Circuit for Measuring Antenna System Mismatch.

A method for checking the match or mismatch of a line requires a sweep generator, an oscilloscope, a crystal diode, and several resistors and capacitors. The circuit is shown in Fig. 60. First the sweep generator output is matched to the transmission line by connecting two 120-ohm resistors and a 50-ohm resistor as shown. (We are assuming here a 300-ohm transmission line and a 50-ohm generator output impedance.) Next, a crystal diode detector network is placed to the line. The other end of this detector attaches to the vertical input terminal of the scope. Connection is also made to the "GND" terminal on the scope. Finally, there is a wire which goes from the sweep generator to the horizontal input terminal of the scope. This is for the purpose of driving the scope beam at the same rate (and in the same manner) as the sweep generator output. Usually this is a 60-cycle voltage.

The equipment is now turned on. The sweep generator is set to sweep over a 6-mc range at the frequency of one of the local channels, say No. 3 (60-66 mc). The oscilloscope is adjusted to provide a trace across its screen. At the start the vertical gain control is turned to mid-position. If the other end of the transmission line is properly terminated--say in a folded dipole--then the pattern on the screen should be a fairly straight line.

Suppose, however, that the other end of the line is open; i.e., it has nothing attached to it. Then what you will see on the scope is a pattern similar to that shown in Fig. 61A. If the other end of the line is short-circuited, the same type of pattern (reversed 180°) will appear. But if the impedance across the other end of the line is gradually made to approach 300 ohms, then the peaks and valleys in the wave will slowly come closer together. See Fig. 61B. And

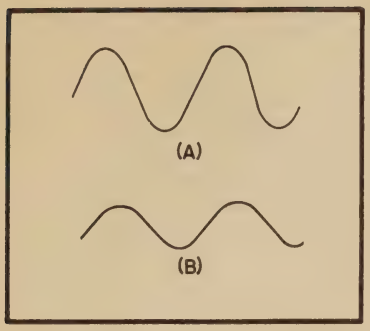


Figure 61. See Text.

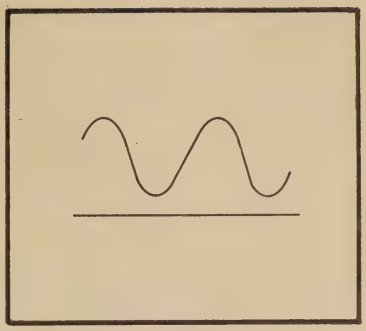


Figure 62. See Text.

when the impedance reaches 300 ohms, a straight line will again be obtained.

The straight line indicates a perfect match. On the other hand, waviness in the pattern indicates mismatch, and the greater the separation of the peaks and valleys, the greater the mismatch.

To understand the reason for this behavior, let us consider briefly the operation of a transmission line. When one end of the line is matched by an impedance equal to the line impedance, then the impedance "seen" at the other end is equal to the line impedance. Thus, suppose a line has a characteristic impedance of 300 ohms and one end is terminated in a 300-ohm resistor. Any circuit connected to the other end of the line will then "see" 300 ohms and this would be true for all frequencies fed into the line.

If the far end of the line is left open instead of having a 300-ohm resistor connected across it, then the impedance "seen" or presented across the other end will depend upon the length of the line and the frequency of the signal fed into it. For example, a frequency which would make the line an even number of quarter-waves long would cause the impedance at the sending end to be very high (actually infinite on a line with no losses). By the same token, a line which was short-circuited at one end would present zero impedance (or a very low impedance) at the other end when the frequency made the line an odd-number of quarter-waves long. Intermediate frequencies would cause intermediate impedance values to appear at the sending end.

When a sweep generator is connected to the line, as in Fig. 60, and it sweeps over a range of frequencies, then the impedance it "sees" at its end (called the sending end) will depend on what is connected across the other end of the line. If the line is properly terminated, i.e., matched, then the impedance at the generator end of the line will remain steady. But, if the opposite end is mismatched, then the impedance presented to the sweep generator will

vary with each frequency in the sweep range. Now, if the generator output voltage is reasonably flat over the swept band, the R.F. voltage at the sending end of the line will vary in the same way that the line impedance varies. By connecting an R.F. detector across this point of the line, the variations can be detected and displayed on the scope screen. The result, for an open-ended line, is shown in Fig. 61A. Of course, if the line is matched, the impedance presented at the sending end will not vary, and the R.F. voltage will likewise remain steady. On the screen this will produce a straight line. Between these two extremes will be found patterns in which there are peaks and valleys and the distance between the peak and valley will be an indication of the extent of the mismatch. Your job will be to make this difference as small as possible.

In presenting the standing wave pattern on the scope screen, it is possible to show it as indicated in Fig. 61 or to display it with a base or reference line. See Fig. 62. For the latter case it is necessary that the sweep generator possess a blanking switch or control which will cut off the generator output on the return trace of the beam. In other words, the frequency is swept once across the band and then the sweep oscillator is cut-off during the remaining half cycle of the driving voltage. In the oscilloscope the beam is active throughout the entire cycle. Hence, when the sweep generator is cut off, the beam forms the base line. This type of presentation is more effective than that shown in Fig. 61 but it does require a sweep generator with a blanking circuit.

It might be pointed out in passing that when any of the patterns of Fig. 61 is developed on the screen, the phasing control on the sweep generator should be adjusted until a single trace is obtained. Failure to do this will generally result in a double pattern and lead to confusion.

The first step in applying this method is to determine if the voltage output of the sweep generator is flat (or reasonably so) over the range it is to be used. Note that this does not mean it must be flat from one end of its dial to the other. Few generators are. All that is required is that the output be steady over the small region to be swept out. Generally this is 6-mc.

The set-up to use is the same as shown in Fig. 60 except that the transmission line is disconnected. The generator output voltage now feeds directly into the detector. Set the generator to the range desired and adjust its sweep for 6-mc. If a straight line is obtained on the scope screen, the generator output voltage is steady over the sweep range. Check the generator output at all frequencies at which the transmission line is to be checked.

The next step is to check an actual system. Suppose we have the transmission line hooked up to a suitable antenna and we wish to determine whether the two match. At the receiver end of the line we would connect our equipment as shown in Fig. 60. (The receiver

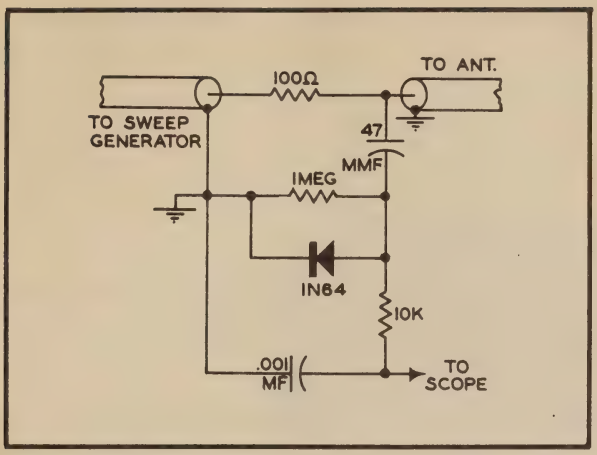


Figure 63. Circuit of Figure 60 Adapted to Coaxial Lead-in Line.

is not attached to the line.) The equipment is turned on and the generator is set to sweep over the desired channel. From the resultant pattern on the screen you can tell at a glance how well the antenna and the transmission line go with each other. It may be that you will find the mismatch considerable in which case you may want to change the line, the antenna, or the spacing of the antenna bars. Whatever you do, the result will be instantaneously visible on the screen.

The same equipment can be used to determine if the transmission line is matched to the receiver. To proceed, connect the line to the receiver and then place the equipment at the other end of the line (with the antenna disconnected). If it is not practical to follow this procedure, then take a 50-foot section (or more) of the line, connect one end to the receiver and the other end to the sweep generator and crystal detector. If the line is twin lead or otherwise unshielded, do not roll it up. However, if the line is shielded (such as coax), it is permissible to roll the line up.

Incidentally, the instrument set-up for coaxial line is just as simple as it is for twin lead. Fig. 63 illustrates how the connections are made.

One final application of this method is the testing of impedance transformers. The most common type of impedance transformer is one that matches a 72-ohm unbalanced line to a 300-ohm balanced line. To determine how well a unit performs this function, take a 50-foot (or longer) section of coaxial cable and connect the sweep generator and crystal diode to one end, as in Fig. 64. To the other end of the cable attach the transformer. The 72-ohm side of the unit connects to the coaxial cable while a 300-ohm resistor is

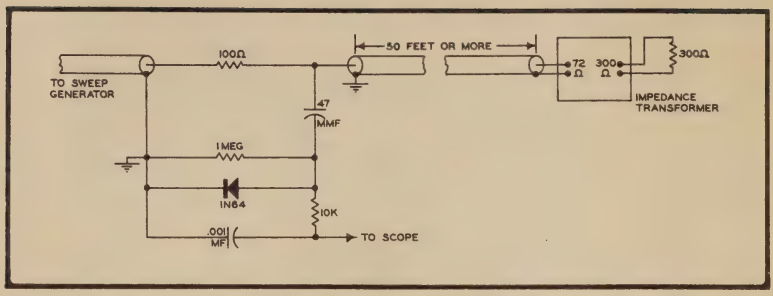


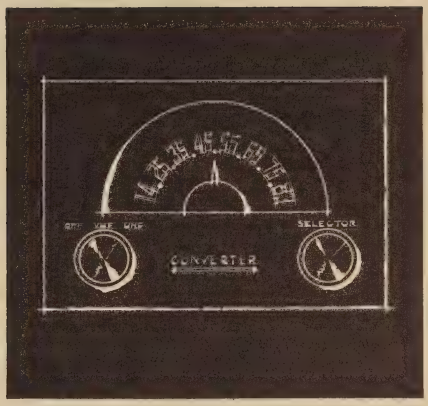
Figure 64. How to Test Impedance Transformers to See How Well They Perform.

placed across the other terminals on the transformer in order to terminate it properly. Now turn the test equipment on and observe whether any standing waves are produced over the channels for which this system is to be employed. A simple test like this of a number of impedance transformers will soon reveal how poorly designed many are.

Undoubtedly the reader will recognize that the transformer could also be tested by using a 300-ohm line and terminating the unbalanced end of the transformer with a 72-ohm resistor. Use the method most convenient to your facilities.

SECTION 4

UHF CONVERTERS



UHF CONVERTERS

The allocation of 70 television channels in the UHF band (470-890 mc) did not occur until the spring of 1952. By that time VHF television, on channels 2 to 13, had been in operation for roughly 6 years and nearly 18 million television receivers had been manufactured and sold. None of these sets were equipped to receive UHF signals directly and obviously something had to be done to prevent them from becoming obsolete with the introduction of UHF stations in their vicinity.

Two solutions for this problem were advanced by the television industry. One was the adaptation of existing VHF tuners to UHF reception by the addition of auxiliary tuning elements. Examples of this were the UHF channel strips that could be substituted for unused VHF channel strips in turret tuners. The other solution involved UHF converters. These units, generally housed in separate cabinets, would receive the UHF signal, convert it down in frequency to one of the VHF channels, and then feed this signal to the antenna terminals of a VHF receiver. From this point the signal would be treated as any other VHF signal.

By means of these two devices, existing all-VHF receivers could be quite easily and economically adapted to receive UHF signals. At the same time, new receivers coming off the various production lines are being equipped to receive either VHF or UHF signals. A

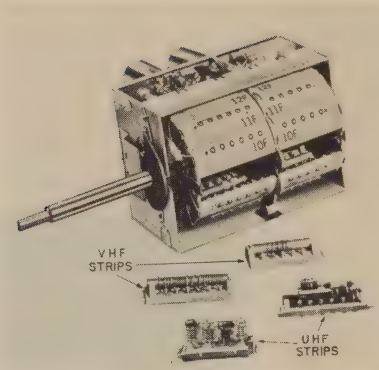


Figure 65. The Standard Coil Tuner with its Tuning Strips in Place. The Bottom Set of UHF Strips would Replace One Set of VHF Strips.

variety of tuning methods and circuit combinations have been developed and are currently in use.

To the service technician, a working knowledge of the operation of these devices is important because he will either be called upon to service or install one or more of them. Toward that end, representative units in each category will be examined.

TUNER STRIPS

There are, on the market, turret type tuners which employ a separate set of R.F., mixer, and oscillator tuning circuits for each channel. These tuning elements are mounted on strips which can be removed from the tuner drum. In the Standard Coil tuner, Fig. 65, there is a set of two strips, mounted edge to edge, for each channel. In the Zenith turret tuner, essentially the same arrangement is employed. See Fig. 66. Each of these turret tuners contain strips for all of the 12 VHF channels. In any one locality, however, the maximum number that will be used will be seven, this being the maximum number of stations allocated to any one community. Thus, if the tuner contains strips for the reception of 12 VHF channels, 5 strips will be unused. Each of these unused strips may be taken out and a UHF strip inserted in its place. In general, one UHF strip will be required for each UHF station it is desired to receive. Again, a 12-channel turret tuner will suffice since the combined number of VHF and UHF stations in any one community will not exceed this number.

A block diagram of the UHF circuits which are contained on the Standard Coil plug-in strips is shown in Fig. 67. There is a tuned input circuit which receives the signal from the UHF antenna. Following this, the signal is fed to a crystal mixer where it combines with an internally generated signal to produce a difference frequency

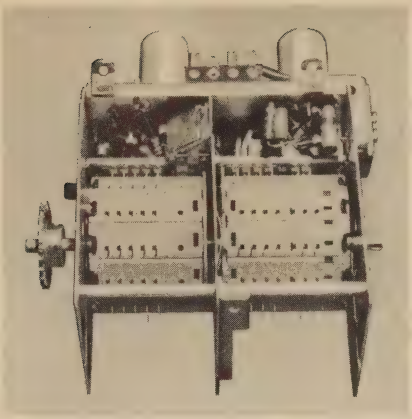


Figure 66. The Zenith Turret Tuner. (Courtesy Zenith Radio Corp.)

that is well below the UHF band. This signal is then accepted by the R.F. circuits of the VHF receiver and treated in the same manner as any received VHF signal.

The mixer on this UHF strip is of the germanium type, especially designed for high-frequency use. This means that it is small in size, possesses a low internal capacitance, and exhibits a good signal-to-noise ratio. A crystal mixer is superior to a vacuum-tube mixer* with the further advantage that it requires no filament power.

Also feeding into the mixer is a locally generated signal which beats with the received signal to produce the stepped-down or difference frequency. This oscillator signal could be developed by a separate UHF oscillator, but for the sake of simplicity, the VHF oscillator already in the set is utilized. What happens is simply this. The VHF oscillator is set to oscillate at some appropriate frequency. Let us say this is 139.25 mc. This frequency is then passed through a crystal (not the mixer) where harmonics of 139.25 mc are produced. A multiplier tuned circuit is peaked to the third harmonic, insuring that this frequency will predominate to the exclusion of other harmonics. This third harmonic, which is 417.75 mc, then beats against the incoming signal to produce a difference frequency which will be accepted by the R.F. amplifier of the VHF receiver.

To take a specific example, let us say that a UHF signal in the 530-536 mc channel is to be received. In this channel, the video carrier is 531.25 mc and the sound carrier is at 535.75 mc. The signal which is used to beat against this is 417.75 mc, using the above figure. Doing this gives us:

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* From about 400-500 mc on up.

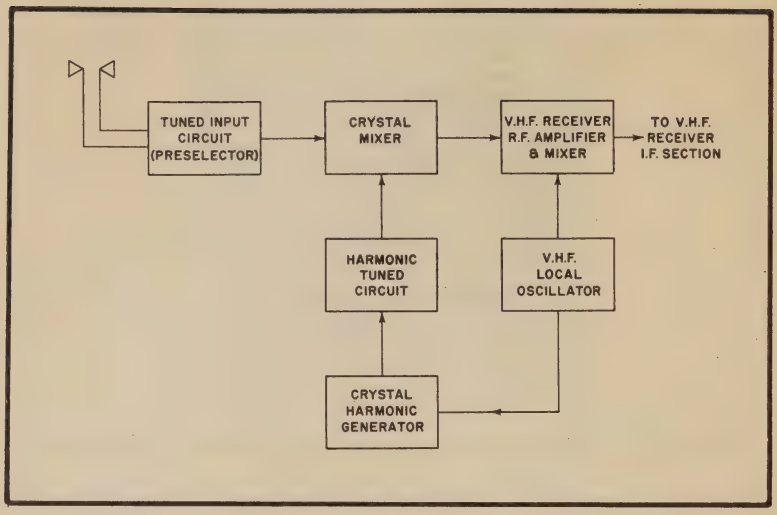

Figure 67. A Block Diagram of the UHF Circuits Contained on the Standard Coil Plug-in Strips.

For the video carrier

$$531.25 - 417.75 = 113.50 \text{ mc.}$$

For the sound carrier

$$535.75 - 417.75 = 118.00 \text{ mc.}$$

These two signals are then accepted by the R.F. amplifier, amplified and then fed to the regular VHF mixer where it beats with the fundamental frequency generated by the local VHF oscillator. This frequency is 139.25 mc and the result of this second beating is as follows:

For the video carrier

$$139.25 - 113.50 = 25.75 \text{ mc.}$$

For the sound carrier

$$139.25 - 118.00 = 21.25 \text{ mc.}$$

Thus, at the output of the VHF mixer, the video and carrier I. F. values are what they normally are for a directly received VHF signal.

From the figures used in this illustration, several interesting facts come to light. First, by using a harmonic of the VHF oscilla-

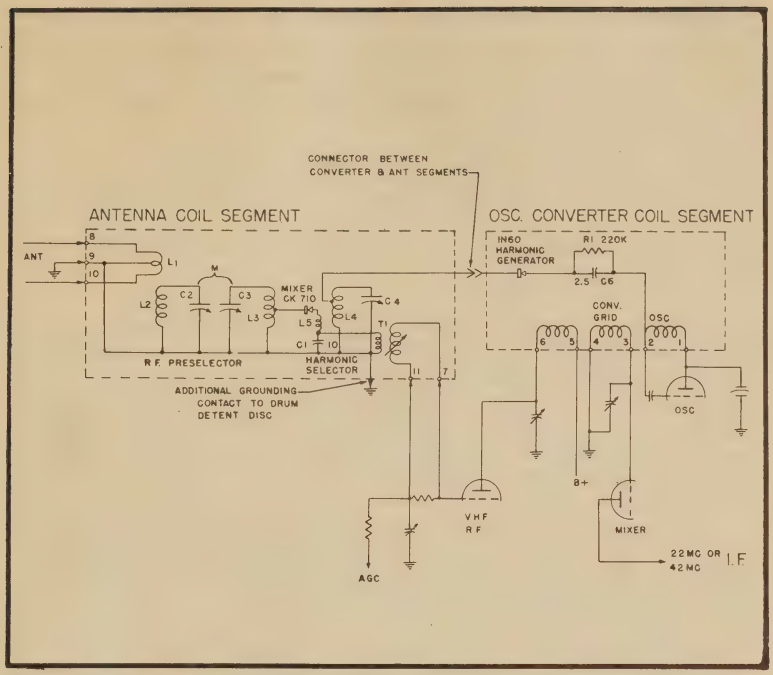

Figure 68. Schematic Diagram of Circuitry of Standard Coil UHF Strips.

tor frequency, we do away with the need for a separate UHF oscillator. A simple germanium crystal produces the desired harmonics from the VHF oscillator signal.

Second, since this strip determines what circuits the VHF R.F. amplifier, mixer, and oscillator will have, the frequencies of these circuits can be of any desired value. In the foregoing example, the VHF oscillator operated at 139.25 mc; the R.F. amplifier was tuned to accept a frequency band extending from 113 mc to 118 mc.

Third, in this type of double conversion, the UHF oscillator mixing frequency must be below the received UHF signal. This is required in order that the position of the video and the sound carrier frequencies are not reversed. Coming into the VHF R.F. amplifier, the video carrier frequency must be below the sound carrier frequency. This is their relative position in VHF signals and must be their position in this type of arrangement.

With this preliminary discussion we can examine in detail the actual circuit on the Standard Coil UHF strip. See Fig. 68. The UHF antenna is connected to terminals 8 and 10 of the strip where

it actuates coil L_1 with whatever signal is received. Through mutual inductance, the signal is transferred to L_2 and then, from here, passes on to the mixer coil, L_3. The mixer crystal is tapped down on L_3 (for best impedance match) so that it receives whatever signal is present in this circuit.

Also feeding into the mixer circuit is a harmonic of the oscillator signal. L_4 and C_4 are resonated to the harmonic which it is desired to pass on to the mixer. Transfer of the oscillator harmonic to the crystal mixer occurs by inductive coupling between L_4 and L_5.

Both signals are now mixed and the difference frequency signal is passed on to the grid of the normal R.F. amplifier of the VHF receiver. The signal is amplified here, then transferred to the mixer where it combines with the fundamental frequency signal of the VHF oscillator. The result of this second mixing should be the normal intermediate frequency. In some receivers this will be in the 20-30 mc range; in others it will fall within the 40-50 mc range.

Note from Fig. 68 that the tuning coils and capacitances for the VHF R.F. amplifier, mixer, and oscillator are also contained on this same strip. This, of course, is in keeping with the VHF practice on turret tuning assemblies.

The multiplier crystal receives its oscillator voltage via R_1 and C_6. The crystal distorts the oscillator currents to develop a series

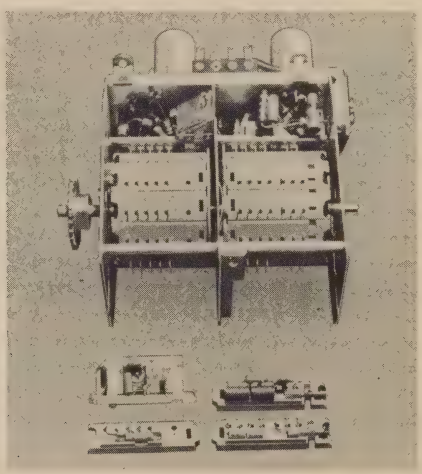

Figure 69. The Zenith Tuner with its UHF and VHF Strips. The Two Strips Closest to the Tuner are the UHF Units. The Ones Underneath are the Corresponding VHF Strips. (Courtesy Zenith Radio Corp.)

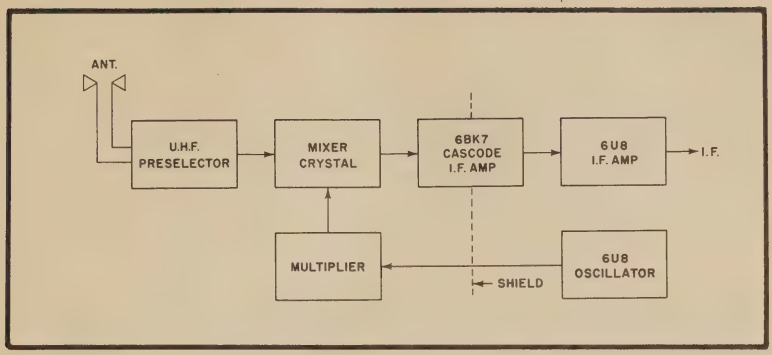

Figure 70. A Block Diagram of the Zenith Tuner with the UHF Strips in Place.

of harmonics. These currents flow through L_4 and C_4 where the desired harmonic is accentuated, then transferred on to L_5 for mixing with the incoming signal.

The Zenith UHF strip, shown in Fig. 69, operates somewhat differently than the Standard Coil strip. The latter utilized the double superheterodyne principle where the incoming UHF signal was stepped down twice before it reached the I.F. frequencies of the VHF receiver. In the Zenith strip, the incoming UHF signal is reduced immediately to the VHF I.F. values. In other words, it operates on the single heterodyne principle.

A block diagram of the UHF strip is shown in Fig. 70. The signal passes first through a pre-selector input tuning circuit and then reaches a germanium crystal mixer. Here it mixes with a suitable harmonic of the VHF oscillator to produce an output signal which has a frequency equal to the I.F. value used in the VHF receiver. This signal is then amplified by the VHF R.F. amplifier (which is now operating at the I.F. frequencies) and the mixer. This latter stage has also been converted to an I.F. amplifier. Following this, the signal is transferred into the normal VHF I.F. system where it is treated as any VHF signal.

Note, then, that in the Zenith strip, the VHF R.F. amplifier and mixer become straight I.F. amplifiers. The VHF oscillator does not feed its signal to the VHF mixer; instead, the oscillator output is transferred to the UHF harmonic crystal by means of a short length of coaxial cable. To cover the entire UHF band, the VHF oscillator must tune between 172 and 234 mc. The third harmonic of the oscillator is used on the low UHF frequencies and the fourth harmonic is used on the high UHF frequencies.

A schematic of the entire circuit of the Zenith UHF plug-in strip is shown in Fig. 71. The incoming signal from the antenna is in-

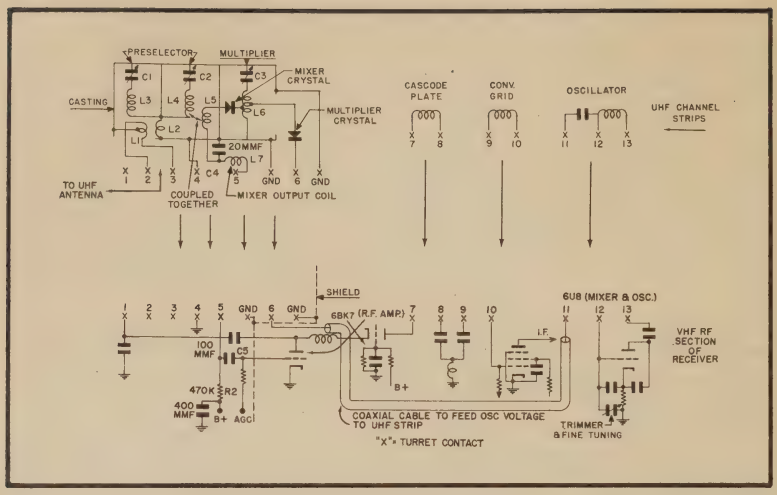

Figure 71. Circuit Diagram of Zenith UHF Strip Shown at Top of Diagram. This Strip Makes Contact with the VHF R.F. Circuits Shown Below.

ductively coupled to L_2 by means of a small two-turn loop, L_1. L_2, in turn, is a mutual inductor forming the coupling between an antenna coil, L_3, and a mixer coil, L_4. In essence, L_3, C_1, and L_4, C_2 form a double tuned input circuit. The coils are wound with flat strip and are only 1/2 inch long and 1/8 inch in diameter. The other UHF tuned circuit on the strip is L_6, the multiplier tuned circuit. To mount these coils and to shield them from each other, a small metal die-casting containing three separate cavities is used. The three tuning capacities, C_1, C_2, and C_3, are provided by the proximity of the top end of the coil to a #1-72 machine screw which enters the housing cavity through a small mounting bushing. No other connection is made to the top end of the coil. Substantial tuning ranges can be achieved with very small capacities by this method because the minimum capacity of the circuit is not increased by connections to a condenser and the parts of a condenser. The minimum capacity of the circuit is approximately 1/4 mmf, and the entire UHF range can be covered easily with three different sets of coils.

The manner in which L_2 is formed may be of interest since it points up vividly the difference between what we have been accustomed to at the lower frequencies and the newer techniques at UHF. Coil L_2, which is the mutual inductance between L_3 and L_4, is provided by a small pin pressed into a recessed hole in the casting between the two coils. The ends of L_3 and L_4 are returned to the casting through this pin, which is thus an inductance common to the two circuits. L_1 is then placed near this junction of L_3 and L_4 and thereby couples its signal into this circuit.

Beyond this double tuned input circuit is the mixer crystal and it receives the incoming signal by having its coil, L_5, positioned near the bottom end of L_4. (L_5, like L_1, is also a two-turn loop of wire.) The other end of the mixer crystal connects to a tap on the multiplier tuning coil and thus both incoming signal and local oscillator signal are present in this circuit. What is produced is the difference frequency and this is fed via C_4, L_7 and C_5 to the grid of the VHF R.F. amplifier tube. This network is a low-pass filter, designed to permit the I.F. difference frequency to pass, but to keep out the UHF currents.

The R.F. amplifier and mixer which follow the UHF crystal mixer operate as straight I.F. amplifiers. In some of Zenith receivers, this means they are tuned to the 21-26 mc band. In the more recent sets, a 41-46 mc I.F. band is employed and the UHF signals would be reduced to these values. The R.F. amplifier has also changed with the years, being originally a single pentode and more recently a double triode cascode circuit.

An unusual feature of this circuit is the introduction of a small positive voltage into the crystal mixer circuit. One end of resistor R2 (470,000 ohms) is connected to B+ while the other end connects into the crystal mixer circuit. Most of the B+ voltage is dropped across R_2, but some small amount appears across the crystal mixer. The d.c. current flow through R_2 and the mixer is on the order of .5 milliampere. The reason for inserting this voltage at this point is to stabilize the operation of the crystal and to insure that it will function properly with a minimum amount of excitation power. The .5 milliampere of current flowing through the crystal automatically causes the unit to operate at the point on its characteristic curve where the curvature is maximum. Also, by doing this, we tend to make the resistance that the crystal presents to the various circuits around it more constant and this, too, aids operational stability.

UHF CONVERTERS

UHF tuner strips represent the most economical method of enabling a set to receive both VHF and UHF signals. Tuner strips, however, are limited in their application to turret tuners of the type described. They cannot be adapted to the millions of television receivers which employ other forms of tuning. For these latter sets, the simplest approach to the problem of UHF reception is by means of an auxiliary UHF converter. The converter, possessing its own cabinet, would be placed on top of the VHF receiver cabinet. See Fig. 72. Antenna connections would be made to the converter, with the lead-in from the UHF antenna generally going to one set of terminals and the line from the VHF antenna attaching to another set. Final connection is then made from the converter output terminals to the VHF receiver input terminals.

A switch on the converter determines the signal which the VHF receiver obtains. If a UHF station is being received, then it is the

Figure 72. A UHF Converter in Place Ready to be Used. (Courtesy P. R. Mallory & Co. Inc.)

stepped down or converted UHF signal which is directed to the VHF receiver. On the other hand, if a VHF signal is desired, the selector switch is placed in the VHF position and the signal on the VHF lead-in line is switched directly to the VHF receiver. During the time that the VHF set operates with incoming VHF signals, the converter is frequently made inoperative. This may be accomplished either by removing all power from the converter or removing the B+ voltages but permitting the filaments to remain lit. In this latter condition switching back to the UHF position enables the converter to return to operation immediately; no warm-up period is required.

Converters are designed for all-VHF receivers. In the newer sets being manufactured, UHF tuning circuits will be incorporated directly into the receiver. In essence the UHF portion of the television receiver may not differ appreciably from the circuits in the converters. Or there may be entirely new methods of approach. After converters have been analyzed, some of the possible systems that may be encountered will be discussed.

The block diagram of a typical UHF converter is shown in Fig. 73. Following preselector tuned circuits, a crystal mixer stage receives the incoming UHF signal and combines this with an oscillator signal of suitable frequency. Since the converter is to be self-contained, it possesses its own UHF local oscillator operating at a frequency which is below the incoming signal. This is necessary in order that the video carrier frequency, after mixing, remain below the sound carrier frequency. In other words, the relative positions of the two carriers must not be altered.

The signal at the mixer output is now applied to an I.F. amplifier. The notation of I. F. is borrowed from the superheterodyne circuit where the amplifiers following the mixer are known as I.F. amplifiers. Actually, here, the I.F. amplifier will have a frequency equivalent to the R.F. amplifier of the VHF television receiver which follows the converter. Keep this distinction between converter I.F. and VHF I.F. in mind to avoid confusing the two.

Beyond the converter I.F. amplifier the signal is transferred to the VHF receiver input where it is accepted through one of the normal channels (2-13) of set. Thereafter it is treated in the same manner as any other VHF signal.

The fact that there is no R.F. amplifier ahead of the mixer in the diagram of Fig. 73 may come as a surprise to many readers. All VHF television receivers employ R.F. amplifiers and since it is known that UHF signals reaching the receiver will in general be weaker than corresponding VHF signals, it is natural to expect that R.F. amplifiers would be employed in UHF front ends. The chief reason for not incorporating such a stage is due to its high cost. Not only would the stage require a relatively expensive tube (such as the new pencil triode, for example), but it would also introduce another tuned circuit that would have to be varied in conjunction with the oscillator and mixer tuned circuits. Since a converter is, in essence, only an auxiliary piece of equipment to a standard receiver, its price must be kept low.

An R.F. amplifier would be advantageous in providing gain for the incoming signal and for reducing the amount of oscillator signal which could reach the antenna and radiate to nearby receivers. When the antenna feeds directly into the mixer, oscillator signal radiation can be quite serious unless definite steps are taken to keep this to a minimum. Precautionary measures include (1) insertion of a high pass filter network between the antenna and mixer and (2) keeping the amount of oscillator signal fed to the mixer to a low level. The characteristics of crystal mixers are such that this is possible with careful design.

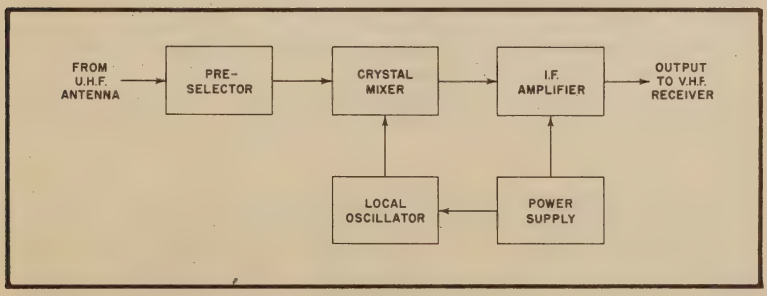

Figure 73. Block Diagram of a Typical UHF Converter.

The practice of using crystals for the mixer stage in place of vacuum tubes is widespread in spite of the fact that crystals introduce an 8 to 9 db loss in the signal. A vacuum tube used as a mixer will provide some gain but a crystal has a better noise figure. If we add to this the fact that crystals are cheaper and their circuits simpler, their popularity becomes understandable.

When a crystal mixer is used in a converter, the noise factor of the entire unit is determined primarily by the frequency which is chosen for the I.F. amplifier following the mixer. For this converter I.F. amplifier, the noise factor becomes poorer as the intermediate frequency rises and consequently it would be best to choose as low a value as possible. Of course, since this signal is to be fed to a VHF receiver, the channel 2 frequencies (54-60 mc) represent the lowest converter I.F. values that can be used.

Working against the selection of low I.F. frequencies is the fact that the amount of power which an oscillator will radiate through the antenna varies inversely as the square of the converter I.F. value. Thus, by doubling the converter I.F. value, the power radiated by the antenna decreases by one-fourth. Finally, a high I.F. value will increase the ability of the converter to overcome image response, cross modulation and other undesirable spurious responses.

The compromise I.F. value which is chosen by most converter manufacturers is 76 to 88 megacycles. This covers channels 5 and 6 of the VHF band and enables the set owner to choose either one in which to accept the converted UHF signal. The channel chosen will be the one which is not in VHF use in that particular locality.

In the interests of low noise, the recently developed cascode circuit is widely employed in the converter I.F. amplifier. A 6BQ7 double triode has been developed especially for use with this circuit. The local oscillator tube frequently chosen is a 6AF4, this being a miniature version of the 6F4. The tube contains silver-plated base pins to minimize losses due to skin effect and short internal leads to reduce lead inductance and resistance. Furthermore, the tube has double base pin connections for grid and plate. These are placed so that the tube can be adapted for use with transmission line tuners. The oscillator operates below the frequency of the incoming signal in order to preserve the correct relationship between the video and sound signals for the VHF receiver. Oscillator injection voltages to the crystal mixer are carefully maintained at a low level in order to reduce radiation through the R.F. input circuit and the antenna system.

An important condition that must be met by these converters is oscillator stability. This condition is of particular importance when the converter is to be used in conjunction with a television receiver employing a separate sound I.F. system. Drifting of the converter oscillator frequency would necessitate continual retuning of the receiver, an undesirable feature from a merchandizing point of view.

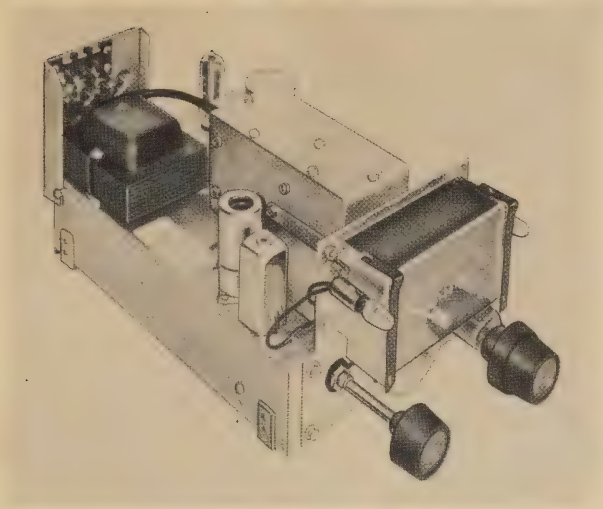

Figure 74. Chassis View of DuMont UHF Converter.

Somewhat greater latitude of oscillator drift is permissible when an Intercarrier set is used. However, since the manufacturer has no way of knowing with which type of receiver his unit is to be used, maximum oscillator stability is required.

Let us now examine a number of commercial UHF converters to see how they function.

DUMONT CONVERTER

The DuMont Converter, Figure 74, uses continuous tuning to cover the UHF band from 470 to 890 mc. A 3-section concentric-line tuner, devised by the P. R. Mallory Company, resonates the two preselector circuits and the oscillator to whatever frequency is to be received. Incoming signals pass through the preselector and are then mixed with a locally generated voltage to produce a difference frequency which falls either within channel 5 (76-82 mc) or channel 6 (82-88 mc). A choice of two channels exists in order that the one not occupied may be used. Beyond the mixer the signal is fed to a cascode amplifier where it is amplified and then transferred to the input terminals of a VHF receiver. The latter set would be tuned to either channel 5 or 6.

This is the bald, overall operation of the converter. Now let us examine its circuitry in greater detail. The circuit schematic is shown in Figure 75.

The input to the converter is designed for a 75-ohm coaxial cable. All incoming signals are first passed through a high-pass

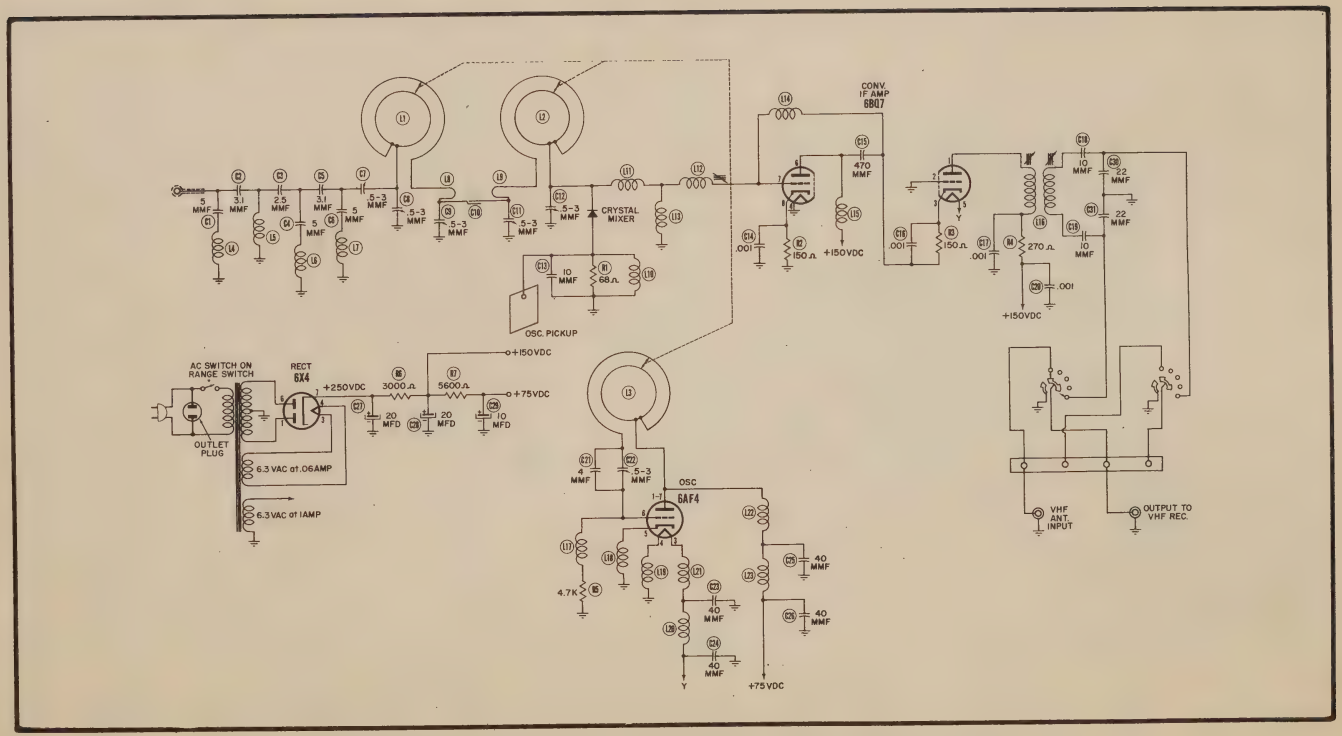

Figure 75. Schematic Diagram of DuMont UHF Converter.

filter before reaching the preselector circuits. The low-frequency cut-off of the filter is in the neighborhood of 400 mc and is designed to prevent VHF signals from entering the converter circuits and causing interference. The double tuned preselector which follows next provides whatever UHF selectivity this unit possesses. Two of the three concentric-line sections tune the preselector elements to the desired frequency. Each section of the preselector is shielded thoroughly and whatever signal passes from the first to the second section must do so by the small capacitive coupling that exists between them. The diagram indicates that an actual physical capacitor is not used but that the coupling is achieved by placing leads from both circuits close together. The end result, of course, is the same.

From the output of the preselector, the signal goes to a 1N72 germanium diode crystal. Voltage from the oscillator is also injected into this circuit by using a small metal plate placed near the oscillator tuning circuit. This type of coupling is essentially capacitive and it possesses the advantage of injecting an increasing amount of voltage as the frequency rises. This will offset the tendency of the oscillator output to drop as the frequency goes up and maintain a fairly constant injection voltage.

The oscillator uses the third of the tuner sections. The circuit is of the ultraudion type which is so widely used in VHF receivers. C_{22} is for the purpose of adjusting the oscillator so that it tracks with the other two sections of the tuner. C_{21} is used for temperature compensation. Note the extensive use of small R.F. chokes in all sections of this oscillator. In the plate and heater circuits, their primary purpose is to prevent the R.F. signal from reaching other sections of the converter from which it might radiate to nearby receivers. In the cathode circuit, the choke helps to maintain this element at R.F. ground potential. And in the grid circuit the choke again prevents the R.F. energy from straying out of its regular channels.

Finally, as a further safeguard against unwarranted radiation, all sections of the tuner are carefully shielded, especially the oscillator.

At the output of the mixer, the difference frequency (or converter I.F.) is transferred to a 6BQ7 cascode amplifier. The coupling network of L11, L12, and L13 permits the I.F. signal to pass but prevents the higher R.F. signal from reaching the 6BQ7. The cascode amplifier sections strengthen the signal and then couple it to the output via transformer, L_{16}. From here the signal is transferred to the VHF receiver. Both 72-ohm unbalanced and 300-ohm balanced outputs are available.

The power supply employs a 6X4 full-wave rectifier to provide +75 and +150 voltages for the 6AF4 oscillator tube and the 6BQ7 amplifier. An r-c filter removes the a.c. component of the rectified voltages.

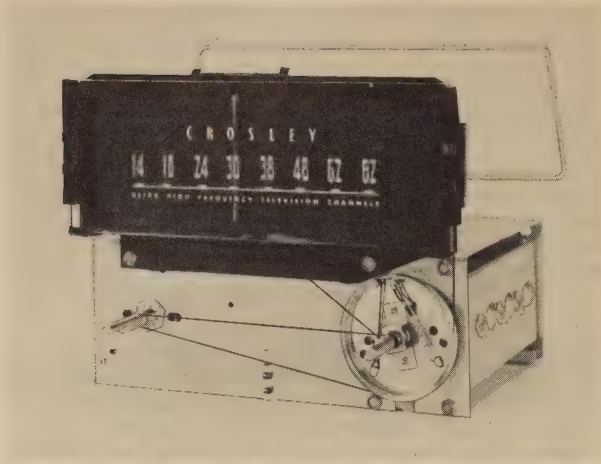

Figure 76. Chassis View of Crosley UHF Converter.

The DuMont converter contains two main knobs. The knob on the right is for tuning and actually it possesses one shaft for coarse tuning on a 6.6/1 reduction ratio and another shaft for fine tuning on a 20/1 reduction ratio. The shafts are mounted concentrically with one being inside the other. The knob on the left is an "ON-OFF, VHF and UHF" switch. When the VHF and UHF antennas are connected to appropriate terminals on the converter chassis, turning this switch to the VHF position turns the converter power off and automatically connects the VHF antenna to the VHF receiver input terminals. With the switch in the UHF position, the VHF antenna is grounded, the converter power is turned on, and the converter output is connected to the VHF receiver input terminals.

CROSLEY ULTRATUNER

The Crosley Ultratuner is a UHF converter which also uses a continuous 3-section concentric-line tuner. The cabinet measures 8-1/8" wide, 6-3/4" high, and 6-1/2" deep. Two operating controls are employed on the front of the cabinet. The tuning control operates a vernier drive of about 15/1 ratio with tuning indicated by a slide rule type dial and the other control functioning as a combination "OFF, VHF, UHF" switch. A chassis view of the converter is shown in Figure 76.

Three tubes are employed, a type 6AF4 oscillator, a type 6BQ7 I.F. amplifier and a type 6X4 rectifier.

A schematic for the Crosley Ultratuner is shown in Figure 77. The input system consists of a double tuned bandpass preselector circuit for maximum selectivity.

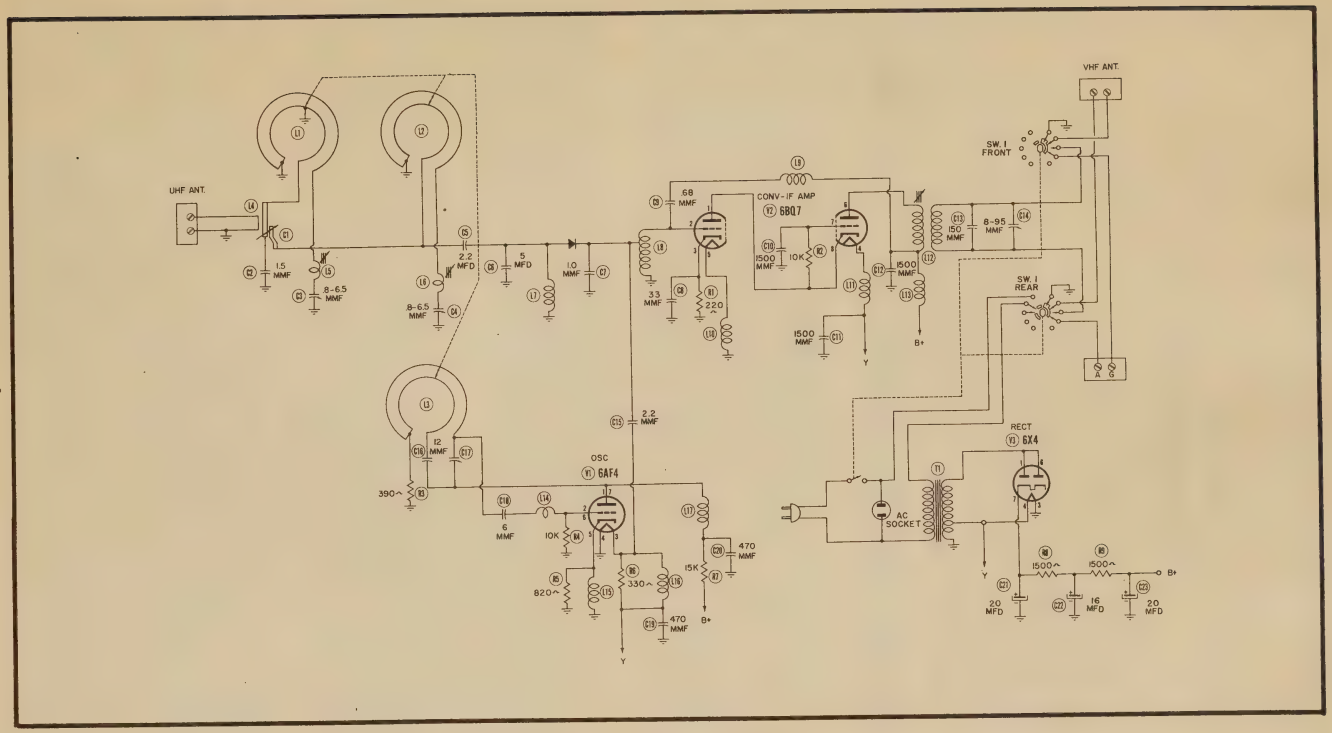

Figure 77. Schematic Diagram of Crosley UHF Converter.

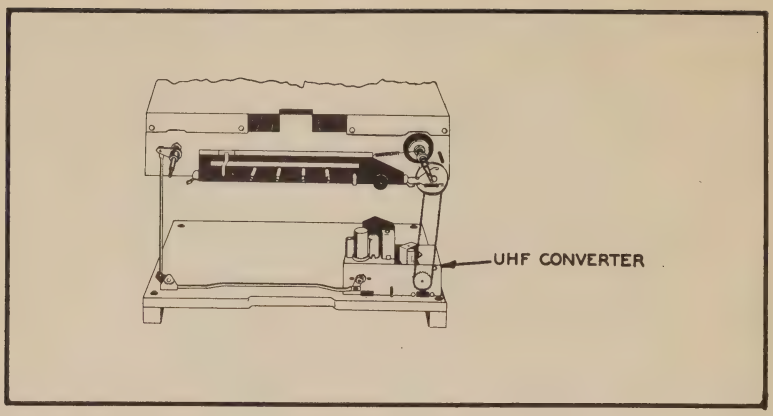

Figure 78. The Crosley UHF Converter Can Be Mounted in the Same Cabinet as the Crosley VHF Receiver.

Excitation of the germanium crystal mixer is provided by coupling an oscillator injection voltage from the high side of the oscillator tube filament through a 2.2 mmf capacitor. Maintaining the high side of the oscillator filament above ground for R.F. is accomplished by the use of a parallel combination of an inductance and a resistor inserted in series with the filament lead. Oscillator radiation is minimized by shielding both the oscillator resonant line section and the oscillator tube and circuits.

From the crystal mixer an intermediate frequency signal is fed to the input of a low noise cascode amplifier stage employing a 6BQ7 tube. The first triode section functions as a conventional grid driven circuit employing neutralization. The second triode section operates as a grounded grid amplifier.

Both the input and output circuits of the cascode I.F. amplifier are designed to maintain desired bandwidth at a frequency of 127.5 ±6 megacycles. Transformer coupling of the cascode amplifier to the converter output terminals through appropriate switching provides a balanced 300-ohm output impedance. The balanced output eliminates picking up interference on the lead to the TV receiver.

One feature of the Crosley Ultratuner is that the converter output is not limited by the frequency of the VHF channels on the TV receiver. In other words it was thought possible to approach nearer optimum operating characteristics by employing an intermediate frequency of about 127 megacycles, which is higher than channel 6 (88 megacycles) and lower than channel 7 frequency (174 megacycles). This tuner therefore is designed to operate primarily with Crosley TV receivers since their VHF tuner is tunable through the entire frequency spectrum from channel 2 through channel 13. It will also operate with any other VHF receiver employing continuous tuning.

However, it will not be suitable for those sets in which the tuner is confined to the twelve VHF television channels only.

The power supply consists of a power transformer and a type 6X4 tube operating as a half-wave rectifier. Conventional RC filtering is used in the rectifier output.

When the Crosley Ultratuner is installed, a UHF antenna is connected to terminals on the unit marked "UHF Ant." The VHF antenna leads are removed from the TV receiver and connected to the converter terminals marked "VHF Ant." A balanced 300-ohm line is then connected from the antenna terminals of the VHF receiver to the converter terminals marked "output". In order to utilize a single control to turn power on and off for both the converter and TV receiver, the receiver's power cord is plugged into the AC power receptacle on the converter chassis.

The combination "OFF-VHF-UHF" switch functions in the following manner.

In "OFF" position power to both converter and TV receiver is off.

In "VHF" position power is applied to the TV receiver, and the VHF antenna is connected to the receiver.

In "UHF" position power is applied to both converter and receiver and the converter output is now connected to the input terminals of the TV receiver.

Figure 78 illustrates how the Crosley UHF converter can be mounted in the same cabinet as the VHF receiver and how the two can be mechanically connected so that operation of the UHF unit is integrated with that of the VHF receiver. A drive chain links the UHF tuner with the VHF tuner (here an Inductuner). On the other side of the UHF converter chassis is the "VHF-UHF" switch. Front panel operation of this switch is achieved by a horizontal and a vertical coupling rod. The lever which is used to flip this switch is mounted on the outer shaft of a combined "CONTRAST" and "ON-OFF, VOLUME" control. The entire arrangement is efficient and well combined with existing VHF receiver controls.

RAYTHEON CONVERTER

Raytheon has developed a UHF tuner which can be combined quite readily with existing Raytheon VHF television receivers. To install the UHF tuner, the VHF chassis is removed from its cabinet, a drive gear is fitted onto the VHF tuner, and then the UHF unit is mounted on the VHF chassis with four screws. See Figure 79. With

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Note: The sections covering the Crosley, General Electric, Stromberg Carlson, and Sarkes Tarzian U.H.F. converters were written by Merle E. Chaney of the staff of Howard W. Sams & Co., Inc.

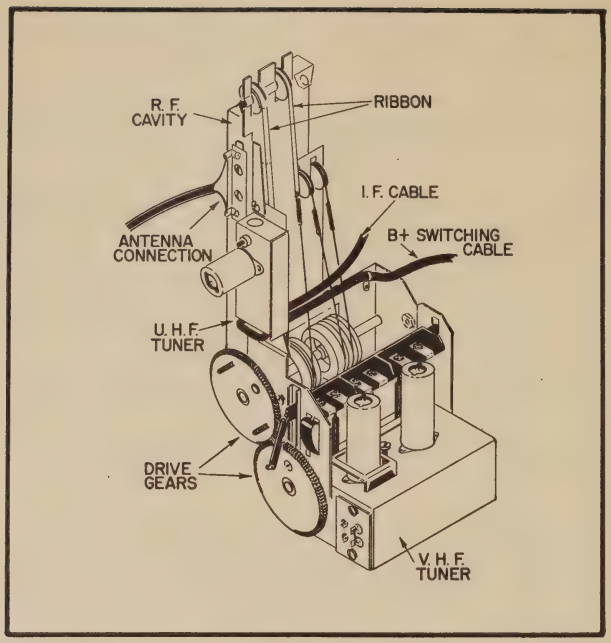


Figure 79. The Raytheon UHF Converter is Installed Onto the VHF Tuner Assembly.

the drive gears, the receiver owner can tune both UHF and VHF units with the same front panel knob.

Electrically, there are two cables running from the UHF tuner to the VHF chassis. One cable couples the converted signal to the VHF I.F. section while the other cable is for switching B plus voltage to either UHF or VHF tuners. Note that here the converted UHF signal does not pass through the VHF tuner section, but instead feeds directly to the video I.F. amplifiers of the VHF receiver. This represents a single conversion process in distinction to the double conversion procedure employed in the preceding converters. It is perhaps for this reason that Raytheon labels its unit a UHF tuner rather than a converter. This distinction between tuners and converters, however, is not always observed in the industry and so the reader must examine each such unit for himself to determine its true mode of operation.

The schematic diagram of the Raytheon tuner is shown in Figure 80.* It contains a preselector input circuit, a crystal mixer, a 6AF4 ultraudion oscillator and a 6BQ7 cascode amplifier. Frequency tuning is accomplished by a double tuned coaxial line or R.F.

* From information furnished by the Belmont Radio Corporation which is a subsidiary of the Raytheon Manufacturing Company.

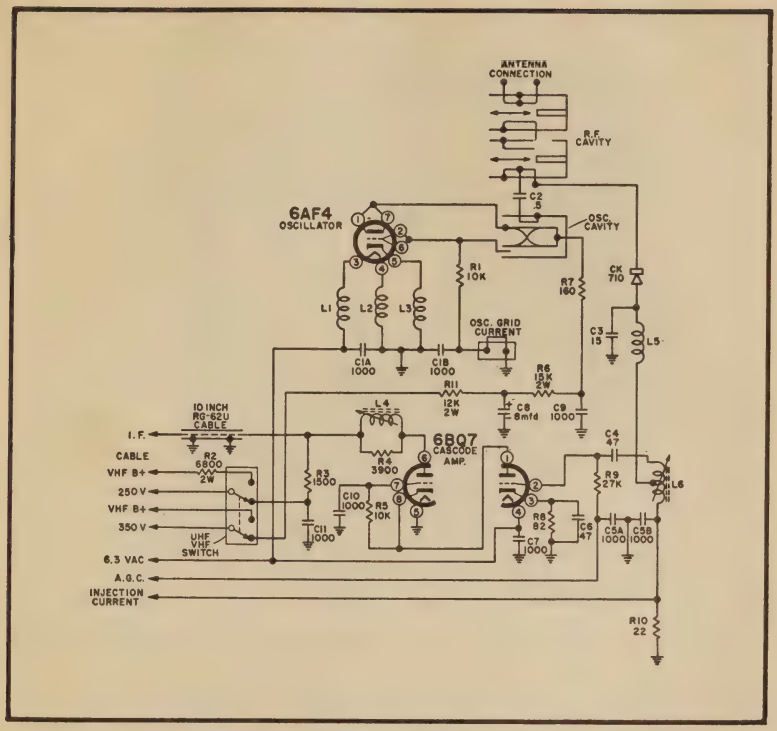


Figure 80. Schematic Diagram of Raytheon UHF Converter.

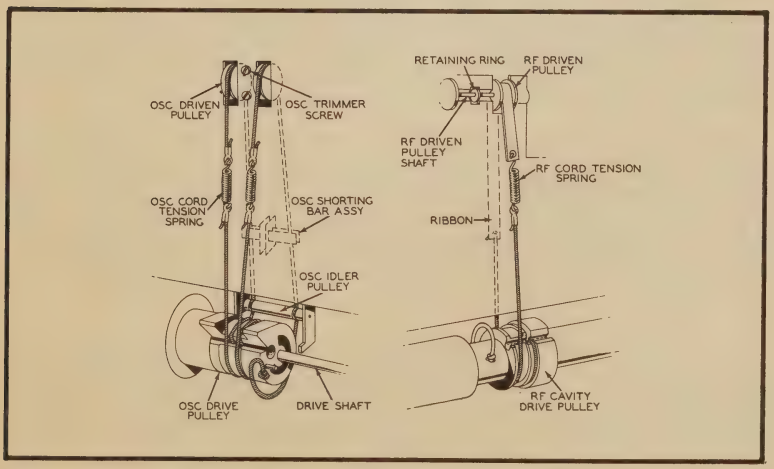


Figure 81. Drive Pulley Arrangements Used In Raytheon Converter to Alter Frequency of Tuning Circuits.

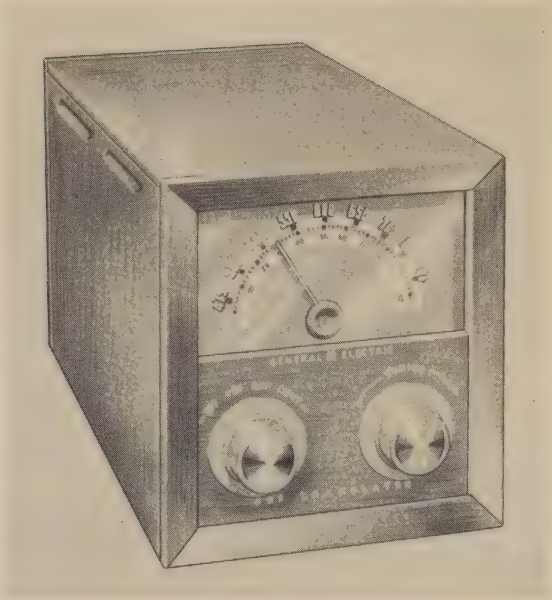


Figure 82. General Electric Model UHF-101 Translator.

cavity. These tuning circuits are basically nothing more than a quarter-wave shorted tuned stub. The electrical length of the lines is varied by a ribbon which is attached to a dial cord and pulley arrangement as shown in Figure 81. In this manner tuning is accomplished similar to varying the length of a tuned stub which would change the resonant length for various frequencies. Signal transfer between preselector tuning sections is by inductive coupling furnished by short lengths of wire.

The oscillator resonant circuit is similar to that of the preselector. Here a quarter-wave shorted parallel-wire transmission line is used and a shorting bar varies the electrical length of the line. There is provision in the grid circuit of the oscillator for inserting a microamp meter to measure grid current. This will serve to indicate not only whether the oscillator is functioning but also how well.

The mixer combines the oscillator voltage and the incoming signal and produces a difference frequency equal to the video I.F. This signal is fed to the 6BQ7 cascode amplifier where it is amplified and then coupled to the I.F. section of the VHF receiver through 10 inches of RG-62U coaxial cable.

The input impedance of this UHF tuner is 300 ohms and the overall bandwidth is 6 to 8 mc. Since there is no R.F. amplifier ahead

of the mixer, the sensitivity of the receiver on UHF will be less than it is on VHF. The manufacturer states that the UHF sensitivity is approximately 150 microvolts.

G.E. MODEL UHF-101 TRANSLATOR

The Model UHF-101 translator developed by General Electric is a UHF converter and provides full coverage for all UHF channels. It is designed to operate with any standard TV receiver switched to channel 5 or 6.

The translator (shown in Figure 82) measures 7-1/2" high, 6-7/8" wide and 13-3/8" deep, and has a power consumption of 20 watts. Two operating controls are provided on the front of the panel. On the right is the tuning control. Tuning is indicated on a dial scale calibrated in frequency with a logging scale for added tuning convenience. On the left is a combination "OFF-VHF-UHF-Light" switch.

Since the converter operates in conjunction with a TV receiver there are three ways in which power may be applied to both units. The TV receiver line cord may be plugged into an AC receptacle on the back of the converter (provided the receiver power requirement is less than 300 watts); the converter line cord may be plugged into an AC receptacle on the TV chassis if this outlet is available; or the line cords from each unit may be plugged into a wall socket--in which case both units must be turned on and off individually. In the first instance, power to both units is controlled by the converter. If the converter is plugged into the TV set then the television receiver "ON-OFF" switch controls both units.

Additional requirements of the converter necessitate the use of a UHF antenna connected to appropriate terminals, and the connecting of the VHF antenna to terminals on the converter. A 300-ohm lead is connected between the TV receiver antenna terminals and the converter output terminals. This completes installation of the unit.

With the converter installed, normal reception of VHF signals by the TV receiver is provided by turning the function switch to the VHF position. In this position the VHF antenna is connected to the receiver antenna terminals, and the receiver power is turned on if the receiver line cord has been installed in the AC receptacle on the converter.

UHF signals are received when the function switch is turned to the UHF position. In this instance the converter power is turned on and the converter output is connected to the receiver antenna input terminals. The TV receiver channel selector is turned to channel 5 or 6 position. Two factors determine to which channel the receiver should be tuned for accommodating the converter output. The channel to which the converter output is tuned is stamped on the

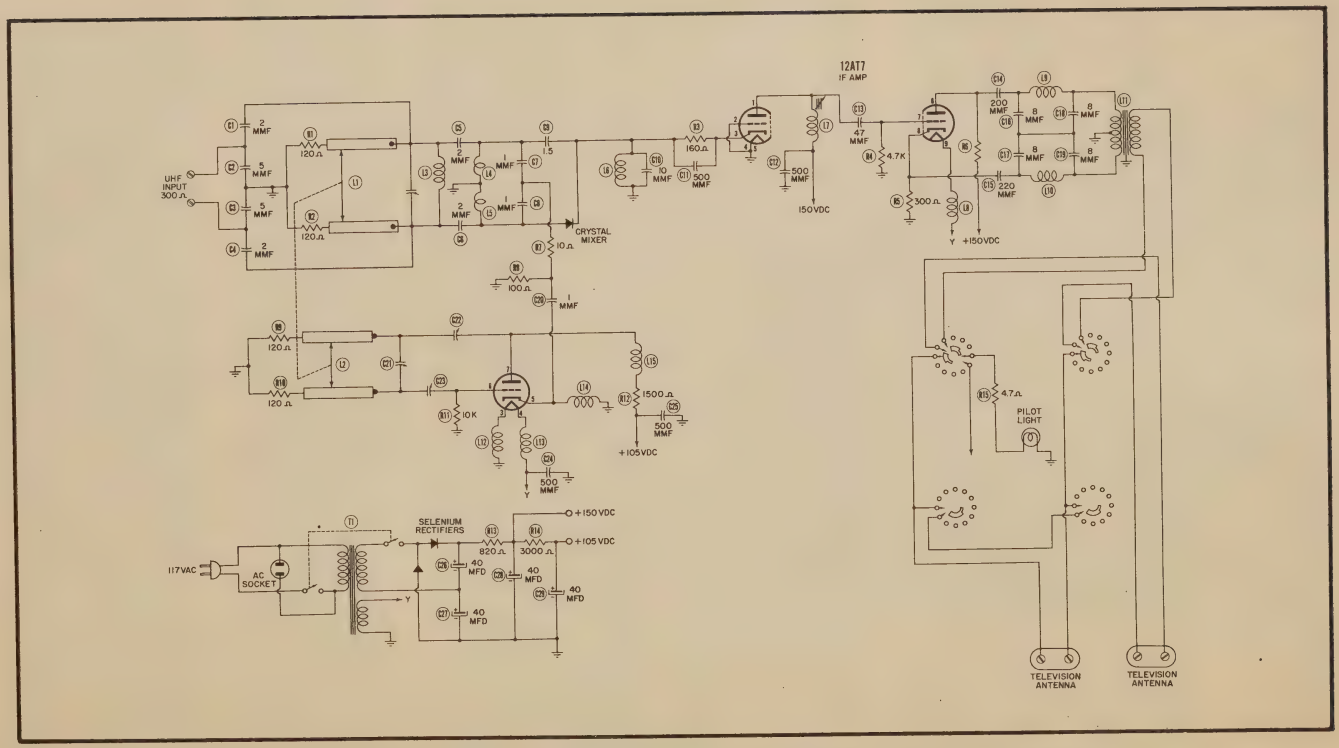


Figure 83. Schematic Diagram of the General Electric Model UHF 101 Translator.

back of the converter chassis. In instances where a strong VHF signal is received by the TV receiver on this channel, the other channel should be employed. Shifting the tuner output 6 megacycles to fall on the unused channel is accomplished by an adjustment located on the back of the converter chassis.

A schematic for the General Electric Model UHF-101 translator is shown in Figure 83. A high-pass filter for rejection of VHF signals is incorporated at the converter input. Also present is an RF preselector circuit for achieving a high degree of selectivity consistent with passband requirements. Preselection aids in image rejection, and reduction of cross modulation in the mixer caused by strong UHF signals. The output of the RF tuned circuits is fed to a crystal mixer type 1N72.

A low level injection voltage obtained from a type 6AF4 oscillator tube provides crystal excitation to produce frequency conversion. The local oscillator operates below the incoming signal, thus providing the correct relationship between video and sound carriers to the VHF receiver.

From the crystal mixer the converted signal is applied to an IF amplifier circuit employing a type 12AT7 dual triode tube. The input triode section is operated as a grounded-grid amplifier. An inductance in the first triode output is adjustable for shifting the signal 6 megacycles to cover either channel 5 or channel 6. The second triode section functions as a conventional amplifier supplying balanced push-pull output to a coupling transformer. The secondary of the coupling transformer is connected through appropriate switching for providing an IF signal to a VHF receiver.

The power supply consists of a power transformer for providing converter filament voltage and higher voltages to a voltage doubler rectifying circuit. A switch in series with the primary of the power transformer applies power to the converter power transformer and to the AC receptacle on the converter chassis. This switch is closed when the function switch is in "VHF, UHF, and Light" position. Therefore, in VHF position the converter filaments are lit. A warm-up period then is not required when switching from VHF and UHF position.

Another switch operated by the function control is in series with the high voltage secondary winding and remains open on VHF position, removing voltage from B+ circuits in the converter. In "VHF, UHF, and Light" position the switch is closed, thus applying B+ to appropriate circuits.

General Electric also produces a UHF converter which can be mechanically linked to the station selector knob of their VHF receivers. This converter, known as UHF-103 Translator, will receive any three UHF stations by adjustment of its tuned circuits. The technician, at the time he installs this unit in the VHF receiver, selects the desired three UHF signals.

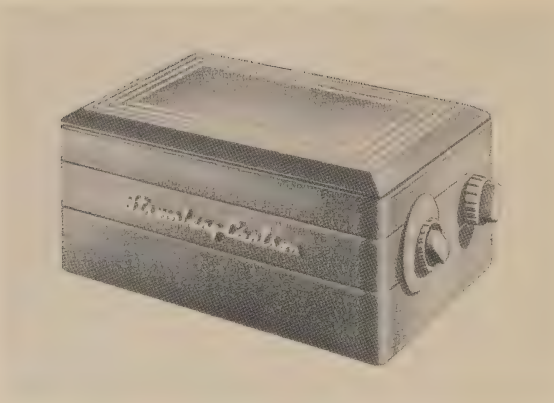


Figure 84. Stromberg-Carlson UHF Converter.

STROMBERG-CARLSON UHF CONVERTER

A UHF converter developed by the Stromberg-Carlson Company provides full 70 channel UHF tuning. This converter is designed to operate on all Stromberg-Carlson television receivers as well as with certain other sets.

Physically, the unit shown in Figure 84 is contained in a cabinet styled in green leatherette and measures 8" wide, 4" high and 6" deep. Figure 85 shows a top chassis view of the converter unit. The weight of the unit is 5-1/2 pounds and the power consumption is about 10 watts.

Setting up the converter for operation is performed by a few simple procedures. The AC plug to the VHF receiver is inserted in an AC receptacle at the back of the converter unit. Then the AC cord to the UHF unit is plugged into an AC wall socket. The lead from the UHF converter marked "TV Input" is connected to the VHF receiver antenna input terminals, after first disconnecting the VHF antenna. The VHF antenna is connected to the UHF converter terminals marked "TV Antenna". During the converter installation it should be determined whether channel 5 or 6 on the VHF receiver will be used to receive the converter output. Since adjacent channels in any one metropolitan area will not be occupied by TV stations, the non-used channel should be employed to pick up the converter output. If signals are normally obtained on both channels, select the channel with the weakest signal. A switch at the rear of the converter is used to shift the IF output 6 megacycles to accomodate either channel 5 or channel 6. This is accomplished without loss of tracking since the preselector circuits are designed for a bandwidth of 12 megacycles.

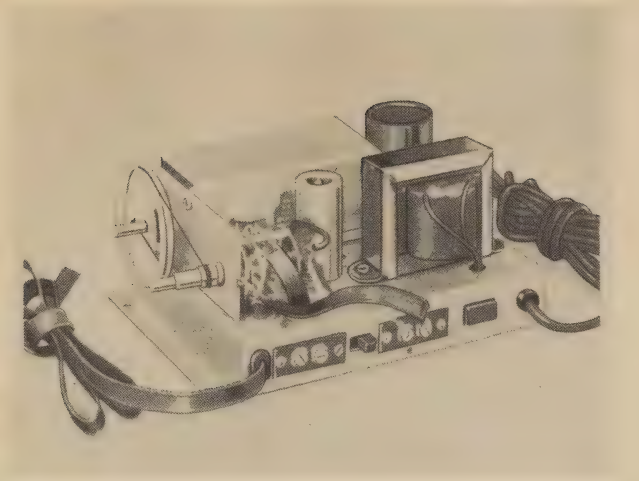


Figure 85. Chassis View of Stromberg UHF Converter.

With the converter set for operation, the power switch on the TV receiver may be left in "ON" position and power to both converter and receiver is controlled by the converter "OFF-ON" switch.

The following combinations are then provided by the three position function switch on the front of the converter unit.

In "OFF" position power to both converter and TV receiver is turned off.

In "VHF" position power to the TV receiver is turned on, the VHF antenna is connected to VHF receiver and filament voltage to the converter tubes is provided.

In "UHF" position power is turned on for both TV receiver and converter with a choice of either UHF antenna, VHF antenna, or built-in cabinet antenna, depending upon signal conditions.

A schematic of the Stromberg-Carlson UHF converter is shown in Figure 86. The UHF signal, from a balanced 300 ohm line connected to the converter input terminals, is capacitively coupled to a double tuned preselector circuit.

Inductive padding is employed in both the antenna and mixer circuits to provide the desired tuning range. Required bandwidth of 12 mc in the preselector is provided by a combination of high-side capacitive and inductive coupling between the antenna and mixer tuned circuits. Grounding of the low frequency ends of the antenna and mixer tuned lines and grounding of the rotor contacts in the antenna section eliminate spurious suckouts within the band.

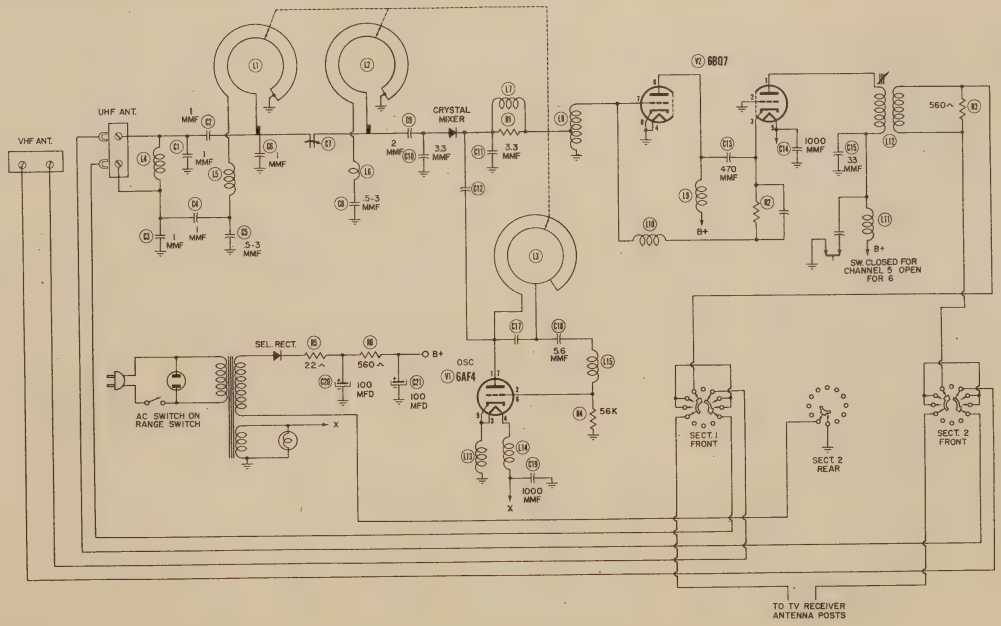


Figure 86. Schematic Diagram of the Stromberg UHF Converter.

A crystal mixer type 1N72 is capacitively coupled to the mixer tuned circuit. The oscillator injection voltage is also fed to the crystal mixer.

The local oscillator is a type 6AF4. A fixed series trimmer capacitor effectively establishes the low frequency end of the tuning range, while the total range and high frequency limit is controlled by a series inductance consisting of the plate and grid leads. Adjustment of this inductance is performed by varying the spacing between the two leads. Dissimilar chokes are employed in the cathode and ungrounded heater leads while resistors are used in the plate and grid return circuits. Grid-plate socket capacity is minimized through the use of a special UHF low capacity socket, thus preventing bypassing of the tuned circuit.

Warm-up drift depends somewhat upon individual tubes and should be nearly complete after about one minute of operation. Using the lowest possible plate voltage consistent with reliable performance also aids in minimizing warm-up drift. Shielding of the oscillator and tuned circuit, plus the low oscillator plate voltage reduces oscillator radiation.

The conversion loss of the crystal mixer is compensated for by the use of a low noise cascode-coupled amplifier. Full 12 megacycle bandwidth is provided by the cascode amplifier input and interstage circuits. In the output triode, however, the plate circuit is designed for 6 megacycle bandwidth.

Shifting of the 6 megacycle bandwidth IF signal to fall in either channel 5 or channel 6 is accomplished by a slide switch. Actuating this switch connects a small capacitor from the B+ end of the output plate coil to ground. Setting this switch for the desired channel is made at the time of installation and should not require further attention.

Balanced output of the converter eliminates the pickup of interference in the lead from the converter to the television receiver.

The use of a self-contained power supply adds to the utility of the converter. The power supply consists of a selenium rectifier connected in a half-wave rectifier circuit, a surge limiter resistor and an RC filter network. A filament winding supplies 6.3 volts to the pilot light and tubes. The low side of the power transformer secondary winding is connected to a wafer on the range switch. Thus, with the range switch in VHF position, the filaments in the converter receive power while the B+ is disconnected. Switching to UHF position connects the B+ circuit making UHF reception available immediately without a time lag for the tube warmup.

RCA CONVERTERS

RCA has come out with a series of three converters. One converter, the Model U1A, will permit the reception of any one (but

only one) UHF television station. Model U2 enables the receiver to pick up any two UHF stations within receiving range. And Model U70 is designed to receive all UHF stations. Thus, while all three units serve essentially the same purpose, they differ from each other in complexity and cost. Let us consider each in turn.

The Model U1A (and a variation, the U1B) is shown physically in Figure 87 and schematically in Figure 88. It employs one tube and a crystal rectifier. Filament and plate power is obtained from the receiver to which it is attached. Models U1A and U1B are identical except for their power cables. The U1A, for example, must be used with television receivers which possess a 6AQ5 audio output stage. This is so because the power cable of the U1A is designed with a 7-pin miniature adaptor socket which will be plugged into the 6AQ5 socket and then the tube will be reinserted into the adaptor socket. The Model U1B is provided with a similar power cable except that it has an octal adaptor socket for use with television receivers which employ a 6K6 or 6V6 audio output tube. Both models may be mounted on the back of the receiver cabinet or other convenient location. However, the selector switch on the unit must be readily accessible to set the unit for UHF or VHF signals as desired.

Schematically the Model U1A (or U1B) converter is quite simple. C_1, C_2, C_3, and L_1, L_2 form the preselector circuit. The mixer is a CK-710 crystal. It is tapped down on L_2 to receive the incoming signals and resistively coupled to the 6AF4 oscillator to receive the oscillator voltage. The difference frequency falls within channels 5 or 6 (as desired) and then transformer coupled (by T_1) to the VHF receiver input.

There are two components in this converter which have jumper wires drawn across them. The jumper across R_6 is removed when

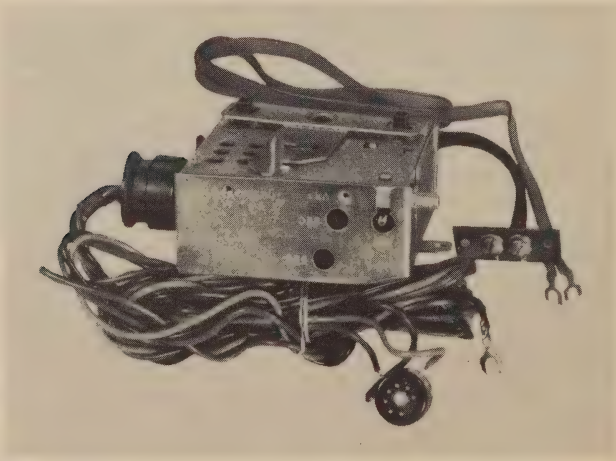


Figure 87. RCA Model U1A Single Station UHF Converter.

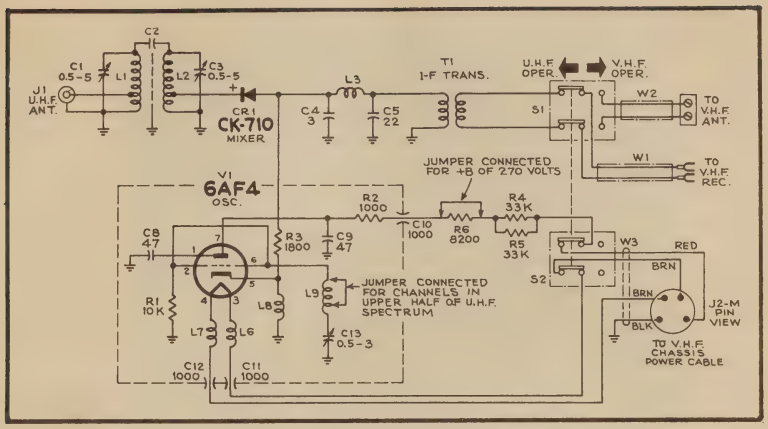


Figure 88. Diagram of RCA Model U1A Converter.

the applied B+ is 370 volts. It is kept as shown when the B+ is 270 volts. The jumper across L_9 is removed when the UHF channel to be received is below channel 45. For channels 45 to 83, it is kept in place.

It might be interesting to observe how this converter is adjusted to receive one UHF channel.* The power cable of the converter is connected to the VHF receiver and the UHF and VHF antennas are connected to their respective terminals. A short section of 300-ohm line is also connected between the converter's output terminals and the VHF receiver's input terminals. The jumper wires mentioned above are removed (or left alone) as required.

The VHF receiver is turned on and set to channel 5 or 6, whichever is vacant in the operating area. Then the UHF selector switch is set to the UHF operating position. The television receiver fine tuning control is turned to the middle of its range and the volume is rotated clockwise until background noise is heard.

The next step is to adjust the UHF selector primary, secondary and oscillator adjustments to the approximate locations as indicated in Table 2.

The selector oscillator trimmer C_{13} is now adjusted until sound from the desired UHF station is heard. This adjustment must be made very slowly for it is easy to pass by the proper operating point without hearing the sound, particularly if the signal is weak.

Once the sound is obtained, adjust the primary trimmer C_1 for the best sound and picture. Next, adjust the secondary trimmer C_3 for best sound and picture.

* As recommended by RCA.

CHANNEL	PRIMARY & SECONDARY	OSCILLATOR
14	6.5 turns CW	1 turn CW
15-16	5.5 turns CW	1 turn CCW
17-19	5.0 turns CW	2 turns CCW
20-23	4.5 turns CW	3 turns CCW
24-27	3.5 turns CW	4 turns CCW
28-32	2.5 turns CW	5 turns CCW
33-37	2.0 turns CW	6 turns CCW
38-41	1.5 turns CW	7 turns CCW
42-44	1.0 turn CW	8 turns CCW
45-46	.5 turn CW	1 turn CW
47-50	.5 turn CCW	1 turn CCW
51-54	1.0 turn CCW	2 turns CCW
55-60	1.5 turns CCW	3 turns CCW
61-67	2.0 turns CCW	4 turns CCW
68-75	2.5 turns CCW	5 turns CCW
76-82	3.0 turns CCW	6 turns CCW
83	3.5 turns CCW	7 turns CCW

The above tabulation is based on the assumption that the Selector is aligned to 670 mc, the condition in which the unit leaves the factory. CW means clockwise. CCW means counter clockwise.

Table 2. Adjustment Chart for the RCA Model U1A Converter.

Readjust the UHF selector oscillator trimmer so that the best sound and picture occur when the television receiver fine tuning control is in the middle of its range. Repeat C_1 and C_3 for best sound and picture.

Note: In adjusting the UHF selector oscillator, it may be possible to obtain sound in two positions of the oscillator trimmer. However, for proper reception of both sound and picture, the oscillator should be lower in frequency than the station picture carrier. Therefore, if sound is heard in two positions of the trimmer, the most clockwise position is the correct one.

The input circuits to the UHF selector tune very sharply--particularly the primary. If the UHF signal is very weak, the primary and secondary trimmers C_1 and C_3 must be in approximately the correct adjustment in order to be able to hear the sound upon adjusting the oscillator trimmer C_{13}. If it is not possible to hear the sound by the method described above, preset the primary and secondary trimmers one-quarter turn in the same direction from previous position and search for the sound by adjustment of oscillator trimmer C_{13}. Repeat this procedure until the sound is obtained. If the above method should not work, try connecting one side of the transmission line to the crystal at L_2 and the other side to the chassis.

Under some conditions interfering beats may be obtained between the UHF selector oscillator and harmonics of the television receiver oscillator which show up as lines in the picture. In some cases these may be eliminated by adjusting the receiver fine tuning for elimina-

Figure 89. The Exterior Appearance of the RCA UHF Model U2 Converter.

tion of the beat, then retuning the selector oscillator core for best sound and picture. As an alternate method switch the television receiver to any vacant channel between 2 and 6 and retune the UHF selector oscillator trimmer C_{13} to obtain sound and picture.

Under some conditions, adjacent channel interference may be experienced if the VHF station is strong and the UHF signal is weak. In such cases, it may be desirable to provide a shielded cable between the UHF selector unit and the television receiver r-f unit.

As a test for drift, turn the receiver off for five minutes then turn it on again. Within approximately one minute it should be possible to receive the UHF station by adjustment of the receiver fine tuning control and without the necessity of readjusting the UHF selector oscillator.

When it is desired to receive a VHF station on the television receiver, switch the UHF selector switch to the VHF position and operate the receiver normally.

Model U2. This UHF converter (Fig. 89) is an elaboration of the U1A and permits the reception of any two UHF television stations when employed with a VHF television receiver. The unit employs two tubes, a crystal rectifier and a selenium power rectifier. See Figure 90. It is housed in a small metal cabinet and is operated by a single control knob.

The Model U2 contains separate preselector circuits and separate oscillators for each of the UHF stations it is to receive. As with the Model U1, each of these sections must be adjusted upon this installation. Once the necessary adjustments are made, the unit will respond only to the two stations chosen. If the owner moves to another locality where different UHF channels are in operation, then a complete realignment will be required.

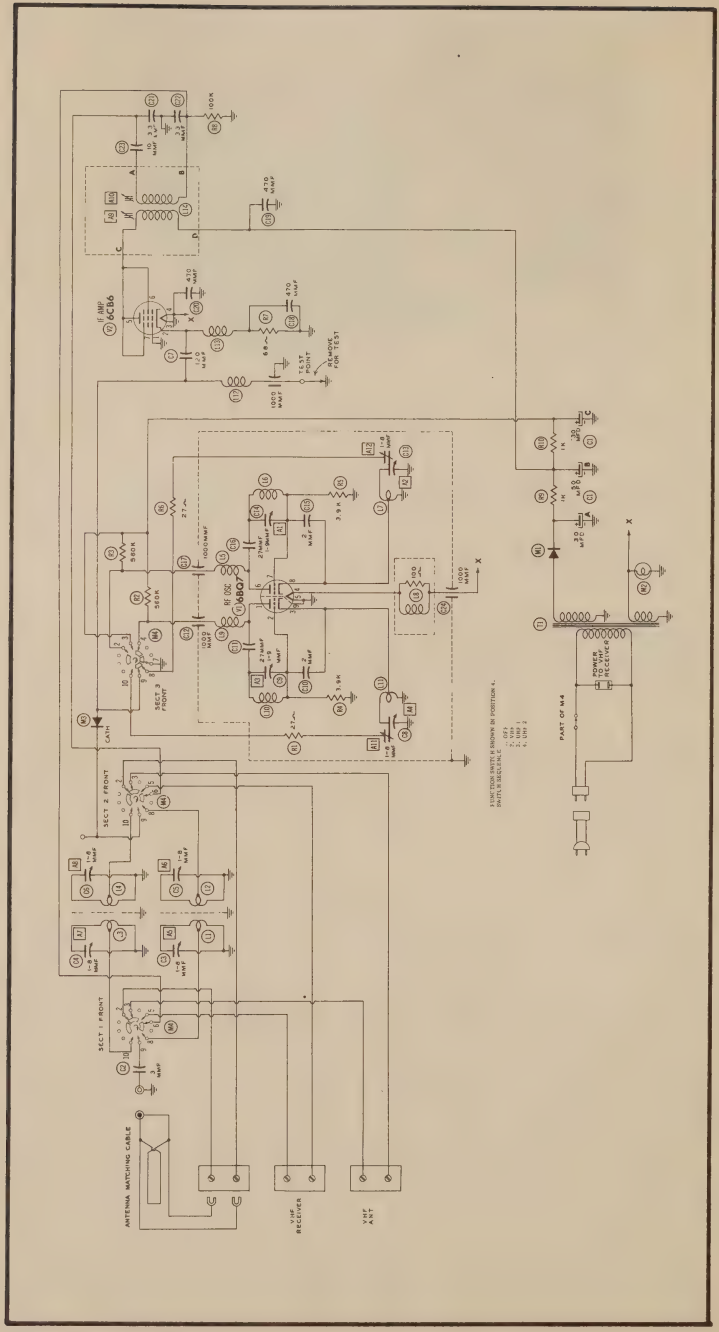


Figure 90. The RCA Model U2 Converter Schematic.

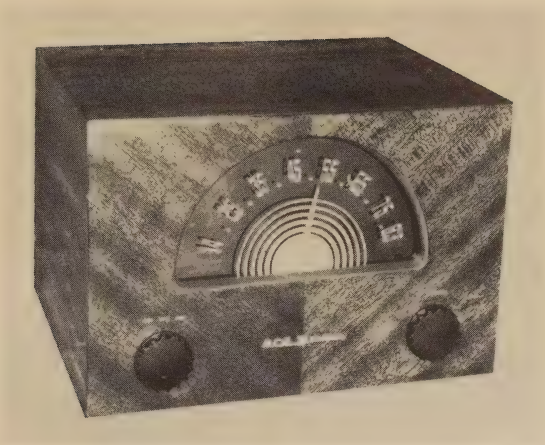


Figure 91. Model U70 Converter. This will Receive any UHF Station.

The oscillators of this converter operate between 200 and 300 mc. The oscillator signal which is applied to the crystal mixer is taken from a harmonic tank circuit located in the cathode leg of the oscillator. The usual practice is to employ the oscillator second harmonic for channels 14 through 46 and the third harmonic for reception of channels 47 through 83. In cases where interference is obtained due to a beat between the UHF oscillator and a harmonic of the VHF receiver oscillator, it may be possible to eliminate it by tuning the UHF oscillator to a different frequency and employing a different harmonic.

The output of the CK710 crystal mixer is amplified by a 6CB6 pentode connected as a triode and then applied to the converter output terminals for transferance to the input terminals of the VHF receiver. Again the signal falls within channels 5 or 6, as desired.

Model U70. The RCA Model U70 converter (Figure 91) permits the reception of any UHF television station within receiving range when employed with a VHF television receiver. It contains three tubes, plus a 5Y3 rectifier, and a crystal mixer. The input impedance to the converter is 75 ohms unbalanced. See Figure 92. However, by using a transmission line balun,* a 300-ohm antenna can also be accommodated.

C_1, C_2, L_1, L_2, and L_3 form a tuned preselector through which incoming signals have to pass before reaching the crystal mixer. The oscillator voltage, from a 6AF4, is inductively coupled to the mixer circuit by the proximity of a special injection wire positioned close to the oscillator tuned circuit. The output signal of the mixer,

* See Section 2.

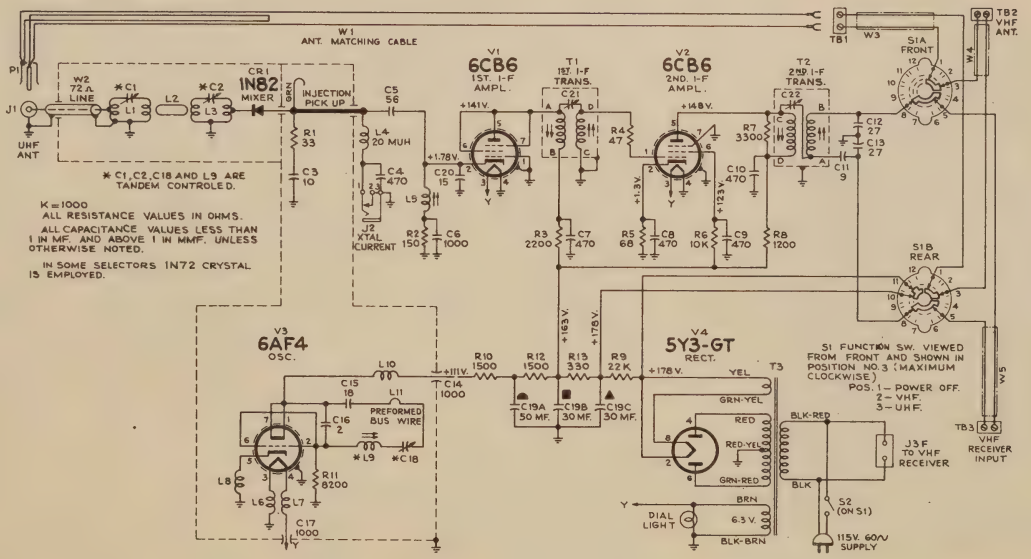


Figure 92. The Circuit Diagram of the RCA Model U70 All Channel Converter.

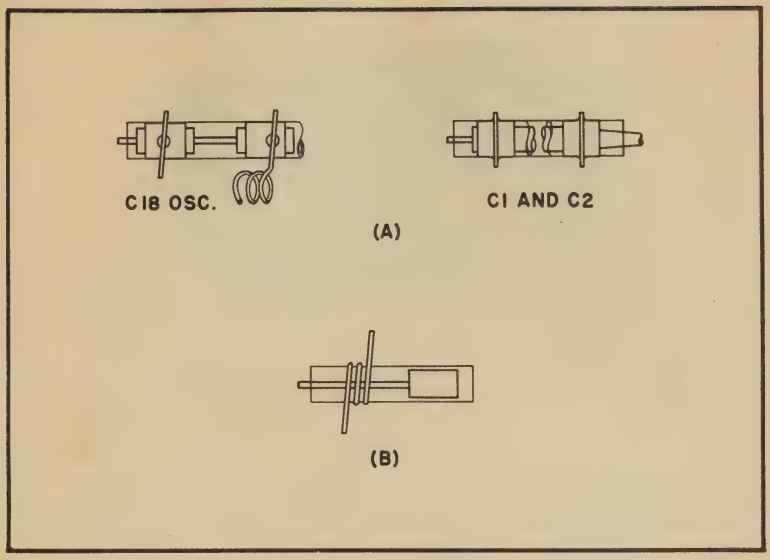


Figure 93. The Physical Appearance of (A) C1, C2, and C18 and (B) L9 in the RCA Model U70 Converter.

falling within channel 5 or 6, is then amplified by two I.F. stages and transferred to the VHF receiver input terminals. The first amplifier, V_1, is a grounded-grid triode-connected pentode while the second stage is operated as a conventional pentode amplifier. The interstage I.F. transformers are overcoupled (by C_{21} and C_{22}) to provide a 12-mc bandpass covering channels 5 and 6. Output to the VHF receiver is balanced at 300 ohms.

The method of achieving a continuous tuning range over the UHF band differs from any of the other tuning methods described in this section. Three capacitors (C_1, C_2, C_{18}) and one inductance (L_9) are all ganged together and varied simultaneously. The capacitors are cylindrical in form, consisting of a fixed outer hollow ring and a movable inner cylinder. See Figure 93A. The amount of capacitance presented by the unit will then depend upon how much of the inner cylinder is within the "shadow" of the outer ring. The greater the common surface area between the two, the higher their effective capacitance.

The inductance, L_9, is varied by altering the position of a small tapered metal cylinder passing through the center of the coil. See Figure 93B. The metal substance is brass, thereby tending to lower the coil inductance the closer it approaches the coil. Hence, at the low-frequency end of the dial (channel 14) the coil core will be farthest from the center of the coil. At this same time, the capacitance presented by C_1, C_2, and C_{18} will be at their highest value.

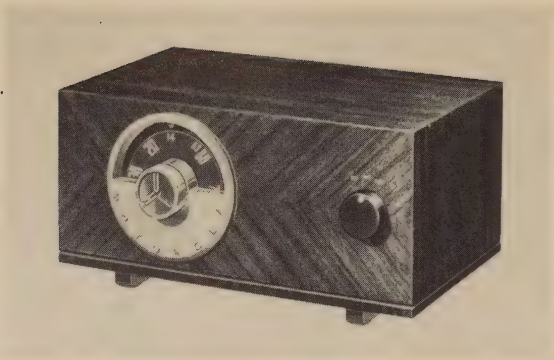


Figure 94. Motorola Model TC-101 UHF Converter.

MOTOROLA

The UHF converter which Motorola has designed is available as a separate unit (Figure 94) complete with its own power supply, or it may be obtained as a "slave" unit which uses the power supply of the VHF television receiver. The latter version is specifically designed for installation in Motorola VHF receivers where a special front-panel cut-out is available to receive the tuning dial of the UHF converter.

The circuit of the self-sufficient (or complete) Motorola converter is shown in Figure 95. A 300-ohm balanced input couples the incoming signal into E_{301}, a shorted quarter-wave coaxial line. This is the preselector circuit and it determines which incoming frequency is permitted to reach the crystal mixer. Also feeding into the mixer circuit, via C_{307}, is the oscillator signal, generated by an ultraudion oscillator. The difference frequency, produced by the beating of the two signals, is then transferred to a 6BK7 cascode pre-amplifier and, after this, to the VHF television receiver via channel 5 or channel 6 (depending upon which is not used in a particular locality).

The tuning mechanism of this converter differs not so much in operation from other transmission-line tuners as it does in the way it achieves this frequency variation. Figure 96 is a simplified schematic diagram of the preselector and oscillator tuning circuits showing the correspondence between the physical tuner mechanism and its electrical counterpart. In the preselector, coil L_{301} is physically only a straight length of wire which is positioned close to the center conductor of the coaxial transmission line. L_1, the coil to which L_{301} transfers its signal, is formed by the tube wall, together with the rod and core assembly (A and B, Figure 96). C_1 is the distributed capacity between the core (B) and the tube wall. As the core (B) moves into the transmission line tube, the resonant frequency is lowered because the electrical length of the circuit increases.

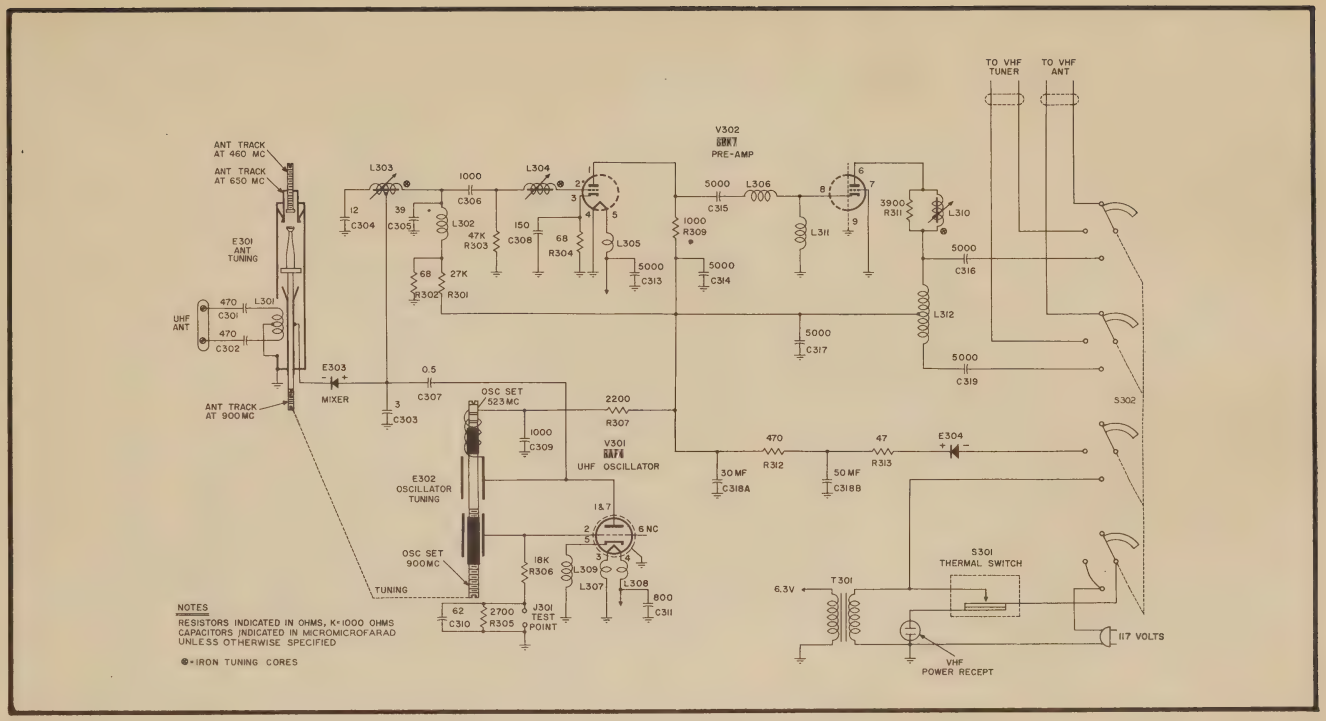


Figure 95. Schematic Diagram of Motorola Model TC-101 UHF Converter.

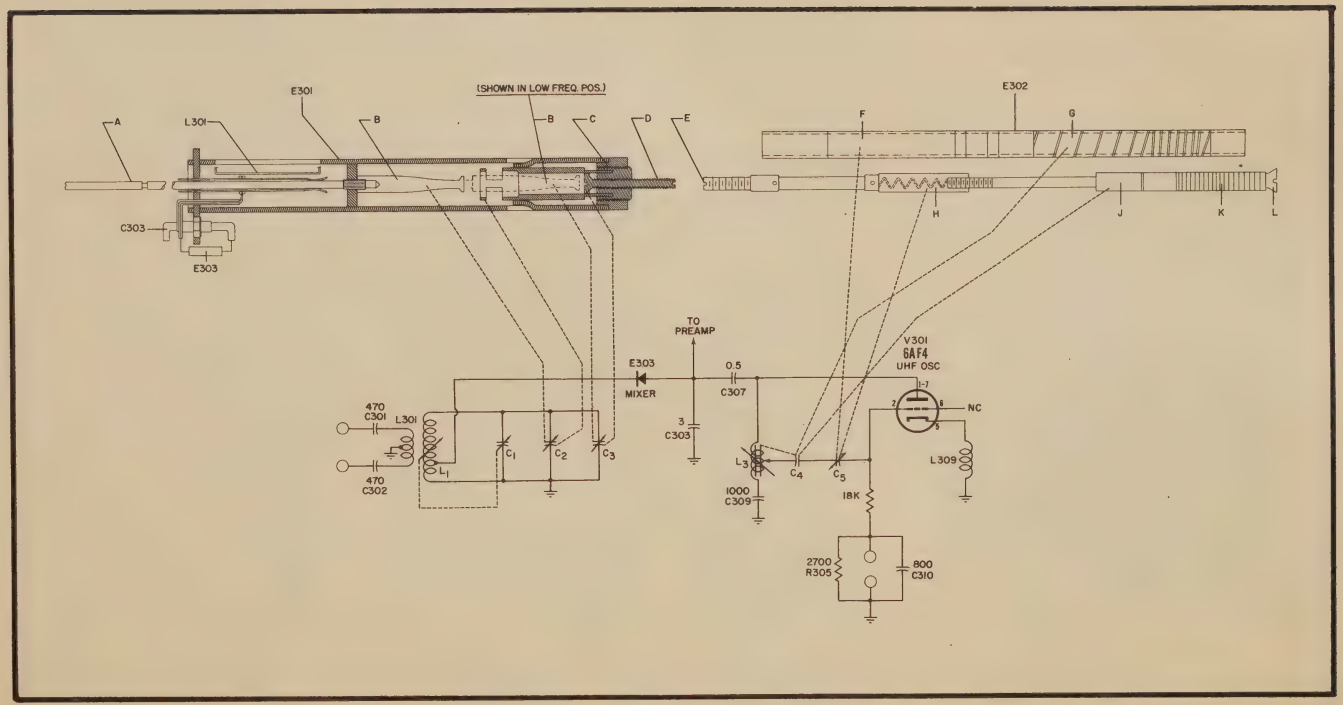


Figure 96. A Simplified Illustration of the Preselector and Oscillator Tuning Circuits Showing the Correspondence between the Physical Tuner Mechanism and its Electrical Counterpart. (Courtesy Motorola)

C_2 and C_3 are added to this circuit to prevent the line from becoming too long. C_2 is formed by the core (B) and the section indicated in Figure 96 while C_3 is formed by the same core (B) and the screw adjustment D. (Remember that a capacitor exists between any two conductors separated by a dielectric.) When the core (B) comes close to the screw adjustment D, the resonant frequency of this tuner is at its lowest point. C_3, therefore, is the initial tracking adjustment at the low end of the UHF band (here, 460 mc). As the core is threaded out (i.e., to the left in Figure 96), the effect of capacitance C_3 decreases and now, toward mid-band (at 650 mc), C_2 comes into play. C_2, thus, is the mid-band tracking adjustment and its value is set by the position of the threaded bushing, C.

At UHF frequencies we are dealing with extraordinarily small capacitance and inductance values and so we must come to expect unusual methods not only in forming these components, but also in varying them.

Leading off E_{301} is a connection to the crystal mixer. The tap is made onto the transmission line and then brought out from the input side of the line. C_{303} is a small by-pass capacitor of the feed-through type.

The local oscillator tuning circuit is perhaps more conventional in form because it operates at a lower frequency than the preselector. L_3, the oscillator coil, consists of a glass coil form with a metallized covering (G, Figure 96) cut to form windings. In addition, there is also a solid metallized section F which, with core H, form the tuning capacitor, C_5. Core J, in addition to tuning L_3, combines with the windings to form capacitor C_4. As its capacitance varies only slightly with the position of J, C_4 is effectively a fixed capacitor and it is shown that way in the equivalent electrical diagram.

The purpose of K, Figure 96, is unique and is really not represented in the circuit diagram. K consists of a series of copper rings which raises the resonant frequency of the unused portion of L_3 to keep its self-resonance higher than the operating frequency. If it did not do this, and the resonant frequency of the unused section came close to the operating frequency of the section being used, it would act as an absorption trap and "suck out" the energy of the oscillator. Result, little or no output at this frequency or range of frequencies.

Finally, E and L are high and low alignment adjustments, respectively.

A three position switch in the converter determines whether the VHF set receives VHF signals directly, or whether it obtains its input from the converter. The third position of the switch feeds A.C. power to both converter and VHF receiver. There is an outlet on the back of the converter and the VHF receiver line cord is plugged into this.

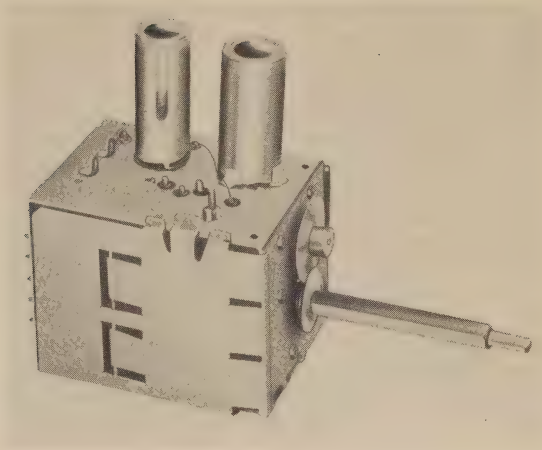


Figure 97. Sarkes Tarzian Type TT16 Tuner.

An added feature of this converter is a thermal switch which prevents the converter from being left on when the VHF receiver is turned off. The current drain of the VHF chassis, by heating and closing the bi-metallic thermal switch, controls the power of the converter. Thus, with the TV receiver obtaining its power through the converter, the off-on switch on either the TV chassis or the converter will turn both units off. Thus, this permits the converter to be left in the UHF or VHF position at all times, as the TV receiver power switch will turn both units on or off.

SARKES TARZIAN UHF TUNER UNITS

A method for the inclusion of UHF in the tuner without sacrificing any of the VHF channels now required has been developed by Sarkes Tarzian. This new tuner, type TT16, shown in Figure 97 is essentially a VHF tuner that has three additional positions for UHF reception.

The input circuit of the TT16 tuner is very similar to that used in Tarzian's latest VHF tuner. A 6AK5 is used as the RF amplifier and a 6X8 as the mixer-oscillator tube. The 6X8 is a combination triode-pentode tube and was especially designed for this application. Through the use of this tube a high conversion gain can be obtained with a low noise figure. In order to provide the additional switch positions for UHF, a 16 position switch is used instead of the 12 position switch. This provides for service on the twelve UHF channels and three UHF positions, while the sixteenth position has no tuning significance and is not used. The reason for the three UHF positions will be explained later.

For operation in conjunction with the TT16 tuner a separate UHF tuner is employed. The UHF tuner itself is continuously tunable over the entire UHF range from 470 to 890 megacycles. A three-section tuning element is employed, two sections for bandpass input and the other for oscillator tuning. A type 6AF4 is used as a local oscillator. This tube is a triode which was specifically designed for use as an oscillator in UHF receivers. A crystal is used as a mixer, the output of which is fed to the proper terminal in the TT16 tuner. This system is not of the double conversion type. Therefore, the output of the mixer is an intermediate frequency signal for a 41 megacycle IF system.

The versatility of the TT16 tuner is illustrated by the fact that switching to one of the two UHF positions located between channel 2 and channel 13 position changes the TT16 tuner to a low noise 41 megacycle amplifier. Compensation, therefore, is provided by the IF amplifier for conversion loss of about 9 db, resulting from the use of crystal mixer in the UHF tuner. A signal, then, is provided to the receiver's IF stages of a level that is comparable to that normally available during VHF reception.

Physically the UHF tuner is designed to mount on the television receiver usually above the TT16 tuner by means of brackets. B+ and filament supply voltages for the UHF tuner are available from terminals on the TT16 tuner.

If the TV receiver comes equipped with a TT16 tuner, it is possible to install a UHF tuner in the field.

Additional controls are not required to operate the UHF tuner. A pulley arrangement between the fine tuning shaft of the TT16 tuner and the UHF tuning shaft permits tuning of either unit from a common control.

The TT16 is supplied for either 21 or 41 megacycle IF systems. For 21 megacycle IF systems double conversion is employed. The UHF tuner then provides a 130 megacycle output to the TT16 tuner. Switching the TT16 to the UHF position located between channel 6 and channel 7 changes the TT16 tuner to a 130 megacycle amplifier. In this position a double superheterodyne system is used for providing a tuner output at 21 megacycles for receiver IFs operating at this frequency.

There are several reasons why a double conversion system is used when a 21 mc IF system is employed. One is the fact that considerable "pulling" is exerted upon the oscillator since it is operating so near the incoming signal. If the oscillator "locks in" with the incoming signal, no output is obtained.

Another very important disadvantage to the use of a 21 mc IF in a UHF receiver is the loss of selectivity. By providing a 130 mc IF signal out of the UHF tuner, both of these disadvantages are

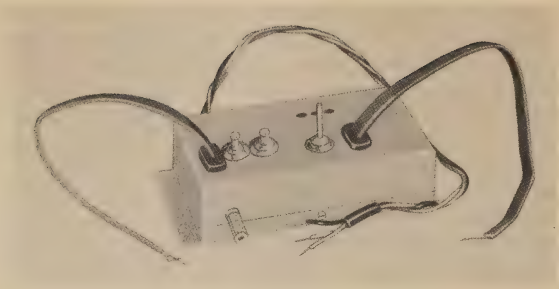


Figure 98. Sarkes Tarzian Single Channel UHF Tuner Unit.

overcome. This signal is then accepted by the VHF tuner and converted to the 21 mc IF.

Another UHF approach taken by Sarkes Tarzian was the development of a single channel pretunable tuner unit. Designed for installation in receivers employing a TT16 tuner in areas where only a single UHF station is available, its particular merit lies in its simplicity and moderate cost. It may be connected on the back of the receiver with supply voltages provided from terminals on the TT16 tuner. A photograph of this UHF unit is shown in Figure 98. The output of this UHF unit is accommodated by turning the TT16 channel switch to one of the UHF positions between channel 2 and channel 13. With the unit pretuned at the time of the installation, operation is automatic and is governed by the TT16 channel selector switch. The two UHF positions between channel 2 and channel 13 make it possible to accommodate the output of two pretunable UHF units should it be desired to receive either of two available UHF stations. This unit, designed for full UHF performance, is offered in two models. One model is available for receiving signals in the lower half of the UHF band, while the other model provides reception from stations lying in the upper half of the band.

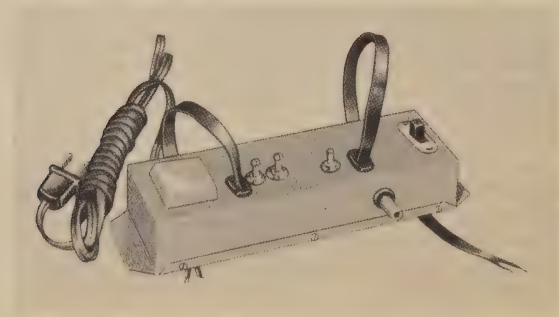


Figure 99. Sarkes Tarzian Single Channel UHF Tuner Unit with Self-Contained Power Supply.

Another version of the pretunable UHF tuner unit is one containing its own power supply. This unit is shown in Figure 99. It is designed to have equal performance to the above described units.

It is claimed that a number of variations are possible with the tuning device described. It is further understood that the TT16 tuner and associated UHF unit are adaptable for specific requirements. In these instances simplification of the TT16 tuner is possible for providing the desired service by limiting the channel selector switch to twelve VHF positions and only one UHF position.

Noise Figure. In dealing with UHF circuits, the term "noise figure" will be heard quite frequently. Bulletins and articles will compare circuits not only as to gain but also as to noise figure and frequently the latter quantity will be far more important than the former. In view of the significance of this quantity, let us determine just what is meant by noise figure and how it affects receiver performance.

The ability of a receiver to amplify a signal is not limited by the amplification which can be obtained from vacuum tubes but by the noise which arises from the tubes and the associated receiver networks. This noise is known as random noise because it possesses no fixed frequency, but extends from zero to frequencies far above any being used today. The noise, therefore, affects every type of receiving circuit.

The noise that is developed in a receiver is due to two sources, thermal agitation in conductors and electron flow through tubes. Thermal agitation arises from the random motion of electrons within a conductor. There is no external voltage applied, but the electrons using their own energy, move to and fro along a conductor. This movement of electrons constitutes a current flow. Since, at any given instant, a few more electrons are moving in one direction than in the other, a voltage is set up in the conductor which is proportional to the net current flow and the value of the conductor resistance. The polarity of the voltage due to thermal agitation changes constantly, electrons moving first in one direction then another. Because of this, there is no definite pattern to the random voltage, or, for that matter, any one frequency at which the energy changes. It has been found that the energy of the disturbance is distributed uniformly throughout the entire frequency spectrum used for communications.

The amount of voltage that is developed by thermal agitation in conductors can be computed from the following relationship:

$$E^2 \text{ (rms)} = 4KTR \times (f_2 - f_1)$$

where

E = the rms value of the noise voltage generated

K = a constant
T = the temperature of the conductor (this is expressed in absolute degrees, Kelvin, which is equal to 273 plus the temperature in degrees centigrade)
R = the value of the resistance of the conductor, in ohms
$f_2 - f_1$ = the bandwidth of the receiver, in cycles.

An inspection of the formula indicates that, with all other factors constant, the wider the bandwidth which the set is designed for, the greater the amount of thermal agitation voltage developed. Note that the actual frequency at which the set is operating is not a factor in the equation; only the bandwidth is important. Thus, a receiver having a bandpass of 1 mc and operating at 200 mc will develop as much thermal agitation voltage as another set having the same bandwidth but operating at 10 mc.

The second source of receiver noise is developed in the tubes. There are several components to this noise.

1) Shot Effect. The current that flows in a tube is not a continuous fluid but a moving congregation of separate particles, the electrons. Noise voltages are produced, even when so-called steady currents are flowing, because at any single instant, the number of electrons impinging on the plate differs from the number reaching this anode at any other instant. Over a period of time, the current is steady, but instantaneously it fluctuates rapidly due to the fact that electrons are particles. It is these instantaneous fluctuations that represent the noise.

2) Noise Due to Current Division. The noise voltages produced by the foregoing shot effect increase as more positive elements are added to a tube. This is due to the division of the current between the plate and the other electrodes.

3) Induced Grid Noise. At sufficiently high frequencies, when the frequency of the signal has a period comparable to the electron transit time, the number of electrons approaching and receding from the grid are seldom equal. This produces an induced grid current which fluctuates irregularly, developing a noise voltage at the grid.

Investigation has revealed that the noise energy developed by these three effects is distributed evenly throughout the frequency spectrum. In this respect it resembles the noise voltage due to thermal agitation. Both together can be combined under the general heading of random noise.

It is customary (and convenient) to express the noise voltage produced by a tube in terms of a noise voltage applied to the grid, the tube itself assumed to be noise free. The r.m.s. value of this voltage is then such that, when amplified by a noise-free tube, it

produces at the output just as much voltage as would be produced by a noisy tube with its input shorted.

In a receiver, the noise that is developed by the first stage is actually the most important because at this point in the system the level of the incoming signal is more closely on a par with the noise level than at any other point in the receiver. In this respect an R.F. amplifier, if used, is more important than the mixer--because whatever noise voltage appears at the grid of the R.F. amplifier is amplified by the tube and appears that much larger at the grid of the mixer. Thus even if the noise voltages of both tubes are equal, that appearing at the grid of the R.F. amplifier is effectively more important because it receives the amplification of the R.F. amplifier while the noise developed at the grid of the mixer does not. Hence, what we seek in the first tube is low internal noise and high gain.

Every receiver must be used with some type of antenna in order that signals be received. Now, every antenna possesses resistance and a noise voltage due to thermal agitation will therefore be developed by the antenna wires and fed to the receiver. We thus have two sources of noise to consider, although at frequencies beyond 100 mc, the noise developed in the receiver is considerably greater than the noise generated by the antenna.

As an indication of the ability of a receiver to take a weak signal and amplify it so that an intelligible output is obtained, a quantity known as a noise figure is frequently used. This noise figure compares the total noise which is present in the output of the receiver (with antenna connected to set) with that portion of this noise which is generated by the antenna alone. This particular ratio is chosen because every receiver must be used with an antenna and since the antenna generates some noise voltage due to thermal agitation in its wires, noise would be obtained at the receiver output even if the receiver generated no noise itself. However, if the receiver introduced no noise, then the ratio of the total noise output of the system to the noise output due to the antenna alone, would be 1. In all receivers, the noise figure is greater than one because the receiver introduces noise.

The noise figure of a system generally rises with frequency because the noise output of tubes has been found to increase with frequency. At the low frequencies, when the input impedance of the first tube is high, the signal from the antenna is generally applied to the grid of the tube through a step-up transformer in order to achieve an impedance match. Under these conditions, the tube noise voltage is small in comparison to the applied signal and a good signal-to-noise ratio is maintained. The sensitivity of the receiving system, then, is limited only by the amount of noise voltage developed by the antenna and this is generally small. With increase in frequency, the tube input impedance decreases and a step-up transformer is no longer needed to match the antenna impedance to the input impedance of the receiver. Tube noise is now on a level

with the received signal and determines how small a signal can be received to develop a useful output. The sensitivity of the receiving system has decreased.

The choice between using or not using an R.F. amplifier in a UHF receiver will thus be governed by the cost of such an addition plus whether or not the noise figure of the set will be improved. The latter, in turn, depends upon the noise figure of the mixer. If this value is high, then the signal-to-noise ratio may be improved by the addition of an R.F. amplifier possessing a fair amount of gain. However, if the noise figure of the mixer is low, then the small degree of selectivity which an R.F. amplifier might furnish would not warrant the expense occasioned by the inclusion of this stage in the receiver.

To illustrate why an R.F. amplifier will not improve the sensitivity of a receiver if it itself does not provide low noise, consider the following. Assume that the noise voltage existing at the grid of a mixer is 10 microvolts and the signal amplitude required to provide a good picture is 30 microvolts. This is a signal-to-noise ratio of 3 to 1. Now, let us add an R.F. amplifier ahead of the mixer which possesses a gain of 8 and has an equivalent noise voltage at its grid of 20 microvolts. The question is: How much signal voltage would be required now to maintain the same 3 to 1 ratio at the mixer grid?

As a first step, let us compute the total equivalent noise voltage at the grid of the mixer. The noise voltage of the R.F. amplifier is 20 microvolts and when this receives a gain of 8, it becomes 160 microvolts at the mixer input. This must be combined with the 10 microvolts of the mixer. However, direct addition is not permissable since the noise voltages consist of many different frequency components. The rms value of the sum of these two voltages is obtained by taking the square root of the sum of the squares, or

$$= \sqrt{(160)^2 + (10)^2}$$
$$= \sqrt{25700}$$
$$= 160.3 \text{ microvolts}$$

This is the total noise voltage effective at the mixer grid. It is interesting to note that it is governed almost wholly by the amplified noise voltage from the R.F. amplifier.

To maintain the same 3 to 1 signal-to-noise ratio, we would need approximately 480 microvolts of signal at the mixer grid. With a gain of 8 available from the R.F. amplifier, the signal at the grid of this tube would have to be 480/8 or 60 microvolts. Thus, by adding an R.F. amplifier, we have made the set less sensitive. Before its addition only 30 microvolts of signal was required; with the amplifier, the value rose to 60 microvolts.

However, an R.F. amplifier would be useful if the mixer equivalent noise voltage was high and the amplifier itself offered good gain with a low noise voltage. Thus, suppose that the mixer noise voltage was 40 microvolts before the addition of an R.F. amplifier. Under these conditions, a signal voltage of 120 microvolts would be required to provide the necessary 3 to 1 signal-to-noise ratio. Using the same R.F. amplifier as above, the total equivalent noise voltage at the mixer grid now becomes:

$$= \sqrt{(160)^2 + (40)^2}$$
$$= \sqrt{27200}$$
$$= 164 \text{ microvolts}$$

The required signal for this much noise voltages is 3 x 164 or 492 microvolts. Dividing 492 by 8, the gain of the R.F. amplifier, we see that approximately 62 microvolts of signal is needed at the input to the R.F. amplifier. Since, the required signal was 120 microvolts without the R.F. amplifier, addition of this stage has doubled the receiver sensitivity.

The important points concerning noise figure to keep in mind are these:

1. An R.F. amplifier, to be useful, must have a low noise figure and, preferably, have high gain. The appealing feature of the new cascode circuits is the small amount of noise they generate.

2. As the noise of a mixer decreases, it becomes more difficult for an R.F. amplifier to improve the noise figure of the receiver.

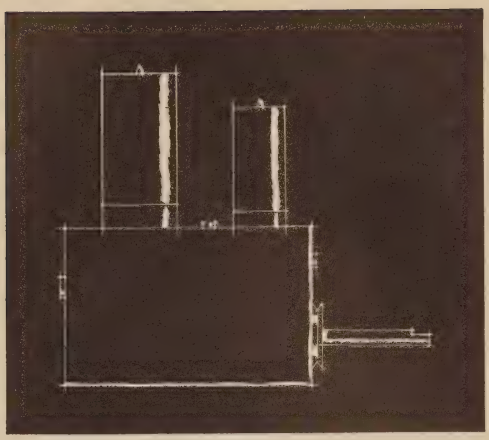
3. The noise generated by the first stage or first two stages of a receiver govern the noise figure of the entire set. Thus, increasing the gain of the I.F. system will not clean up a picture if the R.F. stages are noisy.

4. Low noise is also dependent on circuit wiring and layout. Poor parts replacement can be as destructive as a noisy tube.

5. As the gain of the first stage increases, the noise generated by the second stage can become progressively worse without affecting overall receiver noise figure. This, provided noise in first stage stays low.

SECTION 5

UHF TUNERS



UHF TUNERS

The band in which UHF television has been placed is a difficult one from the standpoint of developing a suitable tuning device. This region is too high for conventional lumped coil and capacitor tuning methods and too low for the resonators which are employed in receivers operating at 1,000 mc and beyond. The methods which have been developed tend to strike a compromise between the lumped inductance and capacitance of low frequency circuits and the distributed inductance and capacitance of UHF circuitry. It is well to remember that inductance can be persented by a straight length of wire, no matter how small and capacitance may exist at any point in the circuit where there is a potential difference and we have conductors close to one another.

As an indication of how small the inductance and capacitance values required in UHF circuits are, consider the input filter shown in Figure 100. This filter is employed between the antenna terminals and the preselector in the Regency UHF converter. Its purpose is to reduce image responses; reduce spurious responses, especially high powered VHF-TV or FM broadcast stations and any strong harmonics of such sources; and finally to reduce oscillator radiation from the converter itself. It is a high pass filter with a cut-off frequency of about 400 mc.

The schematic diagram of this filter, Figure 100, would lead one to believe that it consisted of conventional capacitances and induc-

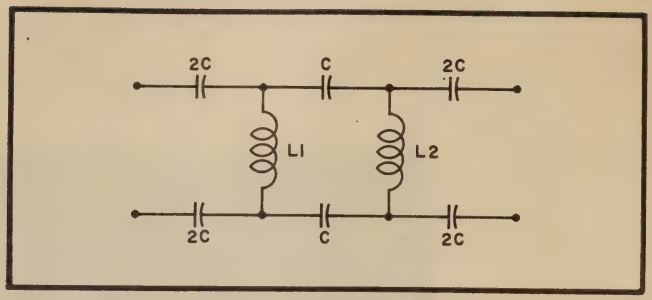


Figure 100. Input Filter Which is Used in Regency Converter between Preselector and Input Terminals.

tances. This could have been the approach but in this instance advantage was taken of the fact that small inductance and capacitance values were required and a filter was evolved which contained no conventional capacitors as such and no soldered joints.

How this was brought about is indicated in Figure 101 where the physical appearance of the filter is shown. Capacitance is obtained by the proximity effect of the wires, that is, by placing them close to one another. To form the smaller capacitance C, one wire from each inductance are brought together and held by a small wire staple. For the larger 2C, one circuit lead and one inductance lead are similarly held over a distance twice as great. The dielectric between the conductors, for all capacitances, is provided by the wire insulation.

The computed capacitance value (C) required by this filter is on the order of 1 mmf. L is only .06 microhenry. This is certainly a far cry from the inductance and capacitance values that most service men are accustomed to.

Transmission Line Tuners. The radio man's acquaintanceship with transmission lines really started with the introduction of com-

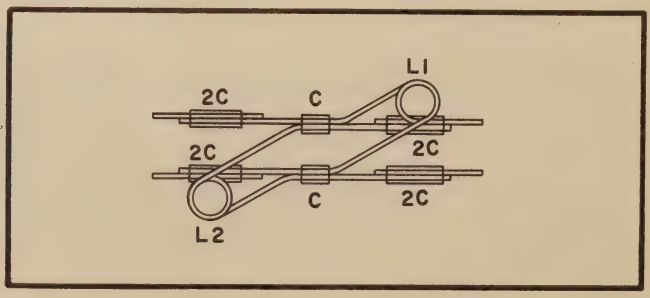


Figure 101. The Physical Appearance of the Filter Network shown in Figure 100.

mercial television. Television receivers required carefully designed antennas and these, in turn, had to be closely matched to the input impedance of the receiver. This matching was done by transmission lines, either of the balanced type as exemplified by the popular 300-ohm twin-lead or by unbalanced coaxial cables.

In his work with transmission lines, the service man has come to recognize that they possess inductance, capacitance, and resistance and because of this, they could therefore be employed as tuned circuits.

Now, the total amount of inductance, capacitance, resistance that a line possesses depends upon its length. In the interests of space economy, it is desirable to use as little of the line as possible in order to cover the desired tuning range. The two lengths most frequently employed are the quarter-wave line and the half-wave line.

The quarter-wave line, as its name suggests, is the length of a transmission line equal to a quarter (or one-fourth) of the length of the wave. Thus, if you are dealing with a frequency of 470 mc, one wavelength is 1 foot. A quarter of this is 3 inches.

At this point it might be well to note that the 3-inch figure is true in free space only. On any line, the velocity of an electromagnetic wave is lower than it is in free space with the result that a quarter wavelength of transmission line would be less than 3 inches. Just how much less depends upon the line construction. For example, on the ordinary 300-ohm twin lead line, a quarter wave (at 470 mc) is only about 80 percent of 3 inches, or 2.4 inches. This figure of 80 percent (or .80) is called the propagation constant and you use it to multiply the free space length to derive the equivalent line length.

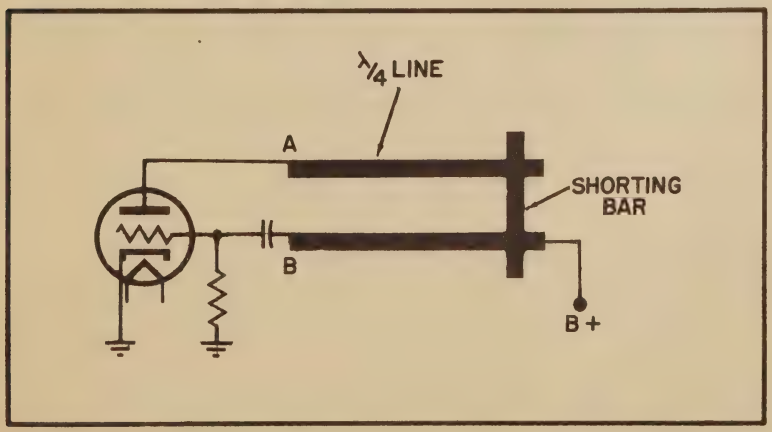


Figure 102. A Quarter-wave Line Used as a Resonant Circuit of an Oscillator.

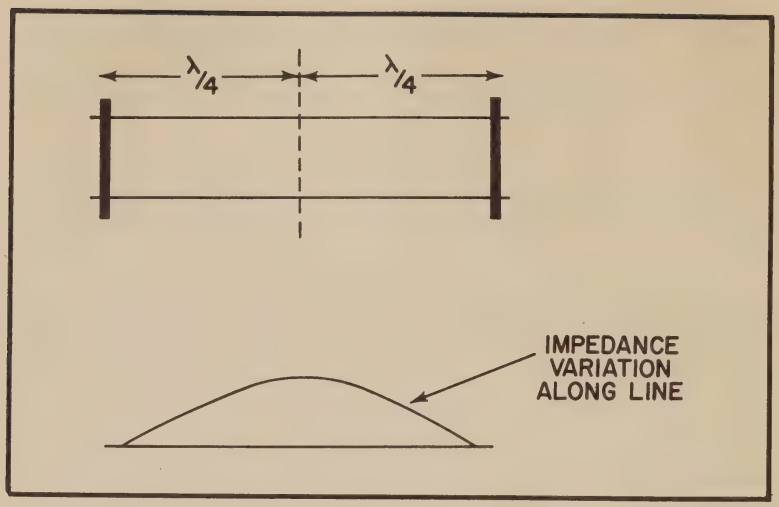


Figure 103. A Half-wave Line can be Considered as Two Quarter-wave Lines Placed Back to Back.

Returning to the quarter wave line, this is the smallest length which can be used as a resonant circuit. And the way the quarter-wave line is employed is shown in Figure 102. (This is the circuit of an oscillator with the line connected between grid and plate). The far end of the line is shorted and the near end is open.

Now, if we were to examine the impedance conditions along this line, we would find that the impedance was zero at the shorted end and highest at the open end. Furthermore, the impedance presented across points A and B would reach its greatest value at the frequency for which this section of line was exactly a quarter-wavelength long.

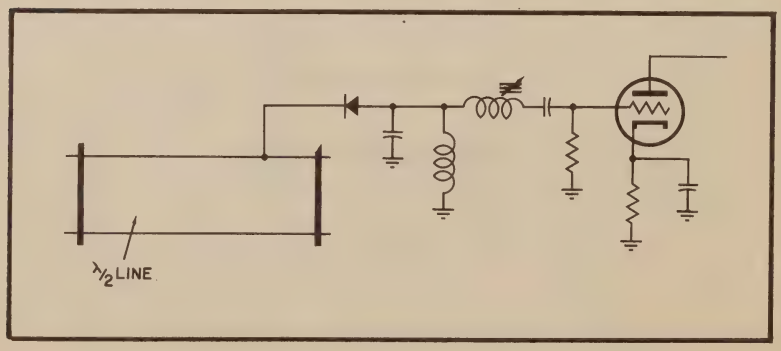


Figure 104. How a Circuit Can be Tapped into a Half-wave Line. See Also Figure 106.

If we raise or lower the frequency (without changing the line length), then the impedance across points A-B would decrease.

We have here an exact parallel with conventional coil and capacitor circuits. That is, for any given coil inductance and capacitance value, resonance occurs at only one frequency. In the transmission line above, inductance and capacitance is determined by line length.

To tune the line, we change its length by using a movable shorting bar. As the bar is moved in toward the tube, the resonant frequency of the remaining or active portion of the line rises. The highest frequency is attained when the shorting bar reaches points A-B, at which time the resonant frequency is determined by the inductance in the wires connecting the tube to the line and the capacitance existing between the plate and grid of the tube.

The second length of line which is widely used for tuning is the half-wave line. This can be considered as two quarter-wave lines placed back to back. See Figure 103. The line is shorted at both ends, which means that the impedance at each end is low, rising to a maximum at the center of the line.

To connect a circuit to this line, we must obviously find some point other than one of the ends since the impedance at both these points is zero. Instead, we connect it as shown in Figure 104. Here it is tapped onto the line at a point where the line impedance matches the circuit impedance. In UHF converters, half-wave lines (when they are used) are found principally in the preselector circuits and connection to the tuned line is made by the crystal mixer. (An example of this will be seen presently).

The reader may wonder why a half-wave line is employed when the shorter quarter-wave line will do the work as well. One reason is that in low impedance circuits, it may be easier to match the line to the circuit by using a half-wave line. Another reason is that the preselector circuit may be operating at a much higher frequency than the oscillator circuit, as we have seen in previously described converters, and in order to gang the tuning controls of both circuits, it may be necessary to use a half-wave line for the preselector and a quarter line for the oscillator. In this way, both shorting bars will travel a similar distance over the entire band.

On the other hand, if the oscillator uses more conventional type tuning elements (because of its lower operating frequency) then the preselector may use a quarter-wave line. There are a number of arrangements possible and each will be governed by its own design.

Transmission line tuners, because of their high Q and simple mechanical assembly, are being used in a number of the UHF tuners and converters. Indicative of the trend in parallel-line tuners is the unit shown in Figure 105. The two parallel lines are circularly shaped in order to gain compactness, as well as to simplify the

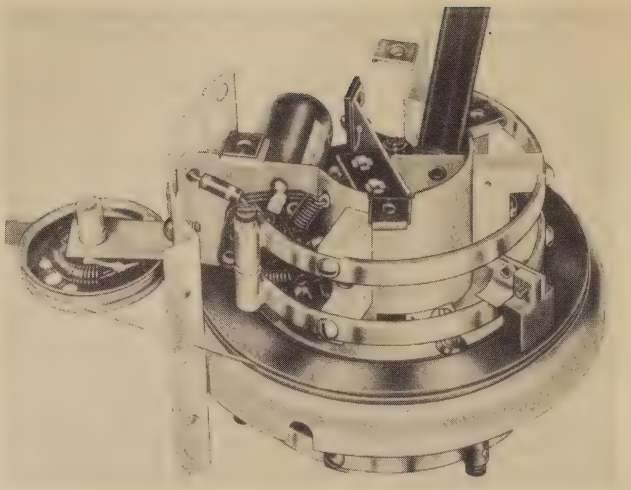


Figure 105. The Regency UHF Tuner. The Tuning Elements are the Circularly-shaped Parallel Lines.

slider and tuner drive mechanism. Tuning is accomplished by using sliders which represent a movable short circuit across the transmission lines. By moving them we can lengthen or shorten the active section of the line and thereby determine its operating frequency.

From Figure 106 it can be seen that two transmission line sections are employed. One section is the R.F. input circuit; the other is for the oscillator. The shorting sliders for each line are ganged together and then attached to a large bakelite ring which is driven by means of a dial cord. The individual circuits are shielded from each other in the manner shown in Figures 105 and 107. All shielding sections are silver-plated over copper.

The overall R.F. circuit of the converter consists of a balanced antenna coupling loup, a preselector transmission line tuning section and a crystal mixer. The preselector circuit uses a half-wave transmission line which is permanently shorted at the mixer end and contains the movable shorting bar at the other end. In covering the UHF band, 470 - 890 mc, the shorting slider has a 4-inch travel. The line is securely supported by means of ceramic stand-off insulators. The mixer crystal is connected to a point on the line where the best impedance match is obtained.

The oscillator circuit is an ultraudion oscillator using a 6AF4 tube. The tuning circuit here is a quarter-wave transmission line which is capacity loaded at its open end. Addition of this capacity tends to shorten the required length of the line.

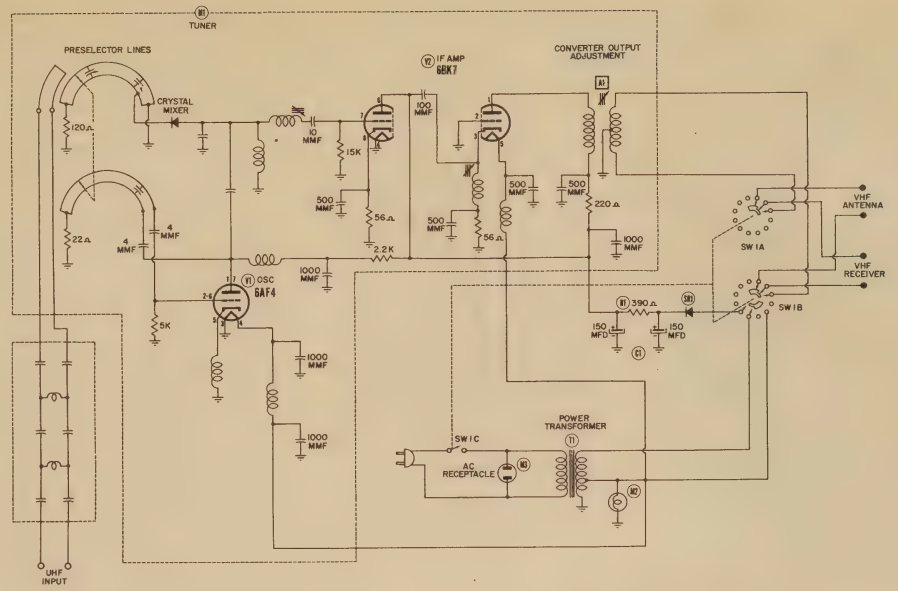


Figure 106. Schematic of UHF Converter Using Parallel-wire Transmission Line Tuner. (Courtesy Regency)

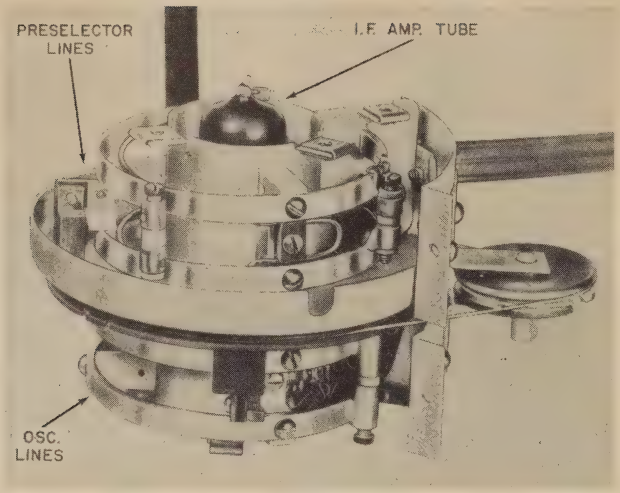


Figure 107. Another View of Regency UHF Tuning Assembly.

It will be noted that whereas the R.F. preselector circuit employs a half-wave length of line, the oscillator uses a quarter-wave length. This is because the local oscillator tunes from 275 to 695 mc while the R.F. preselector tunes from 470 to 890 mc. The fact that the local oscillator frequencies are not exactly half of the UHF frequencies is taken care of by adding a capacitor across the open end of the quarter-wave line. This serves to shorten the line so that each shorting bar will travel over the same distance.

Since the shorting bars of both lines are ganged to the same tuning shaft, adjustments must be provided to insure proper tracking. This is accomplished by using two trimmer capacitors on the preselector lines. One trimmer capacitor is used for adjustment at the high-frequency end and another trimmer capacitor is for adjustment at the low frequency end. On the oscillator tuner line there is a small trimmer capacitor across the open end of the line and this establishes the frequency at the low end of the range.

The output of the crystal mixer is fed to a two-stage IF amplifier. A 6BK7 double triode tube is used. This IF amplifier is aligned to VHF channel 10. Actually, the output circuit of the 6BK7 can be adjusted to any of the VHF channels 8, 9, 10, 11, or 12. This enables the user to choose the channel which is most free of undesirable interferences.

Concentric-Line Tuner. The P.R. Mallory Company, makers of the famous Inductuner, have adapted this unit to the ultra-high frequencies. The newer design employs two metal strips which are placed in parallel circular grooves extending for 270° of the total 360°. See Figure 108. The other ends are the points to which the

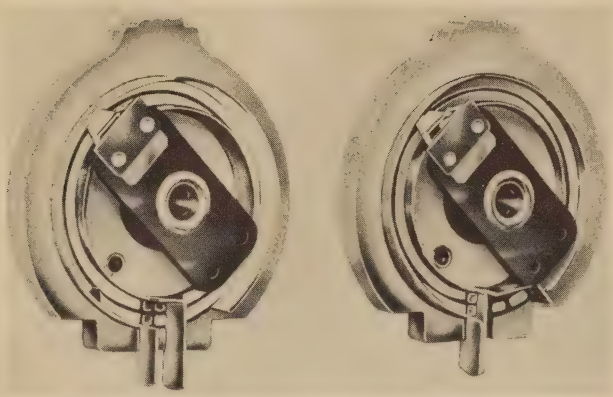


Figure 108. Elements of the UHF Tuner Developed by the P. R. Mallory Co.

circuit components are connected. The length of line which is then active is that section between the open ends and the movable shorting bar. The reason for shorting the far terminals together is to short-circuit any low-frequency interference which may be present. This short also tends to keep the lines balanced and thereby to reduce oscillator radiation. This is especially important in the R.F. pre-selector section.

Three and four concentric line sections can be ganged together on one shaft. To permit tracking, the various tuning elements are shaped differently from each other. The input circuit can be designed to receive an unbalanced line or a balanced line. The circuit shown in Figure 109 possesses a balanced input of 300-ohms.

It will be seen from Figure 109 that transfer of oscillator voltage from the oscillator to the crystal mixer occurs from a tap on the oscillator heater. The capacitance between heater and cathode is of the order of 2.7 mmf and thus the oscillator voltage present on the 6AF4 cathode is led through this capacitance to the mixer circuit. The advantage of such an arrangement is that variations in the mixer circuit will have less effect on the oscillator.

Also shown in Figure 109 is the I.F. amplifier which follows the mixer. Like many others it is a cascode amplifier employing a 6BK7 tube. The I.F. frequency is 82 mc - 88 mc, which places it in channel 6. Actually, the bandwidth is approximately 12 mc wide and consequently either channel 5 or 6 can be used to receive the UHF signal.

General Instrument UHF Tuner. The UHF tuner which was developed by the General Instrument Corporation represents still another approach to a transmission line tuner. Basically it is a silver-plated end-tuned quarter-wave coaxial line. However, instead of

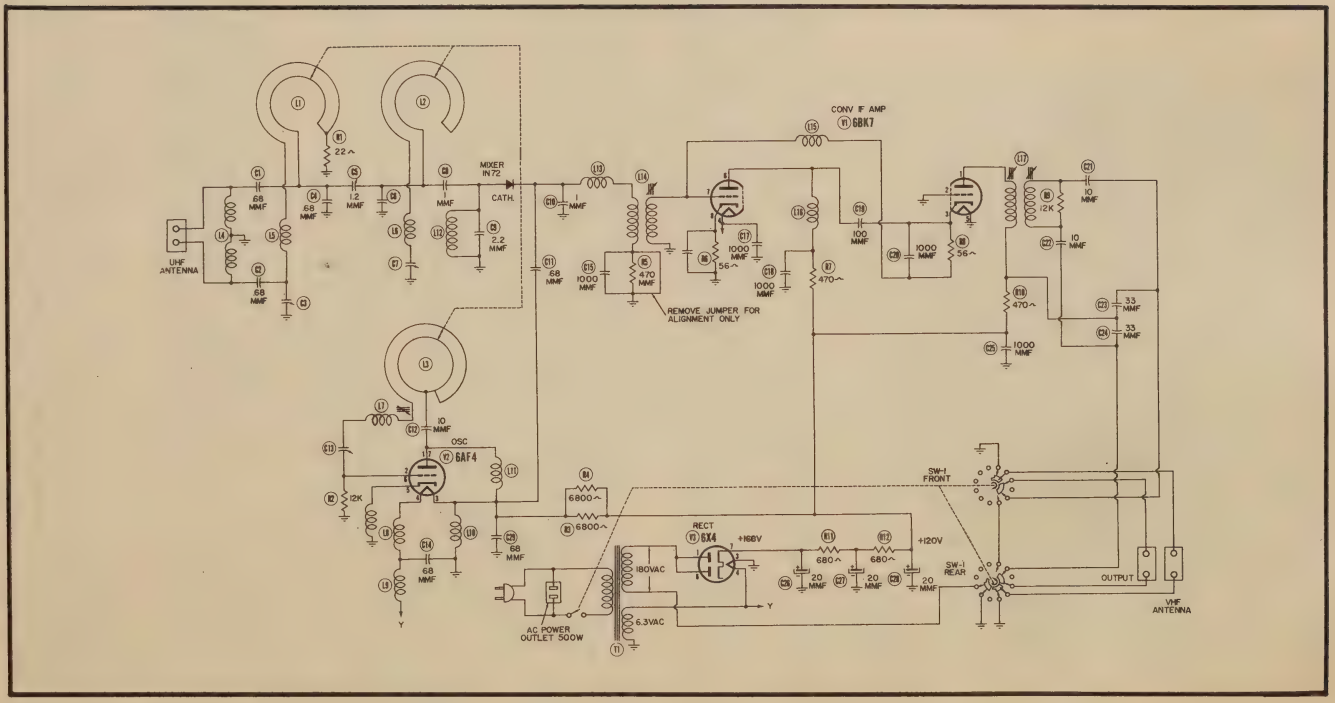


Figure 109. Schematic of a Mallory Converter Using Their UHF Tuner. This Same Tuner is Used by Many Other Manufacturers.

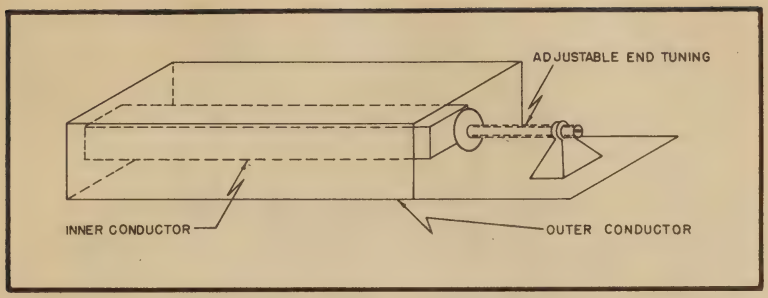


Figure 110. The General Instrument Tuner is Derived from the Above Rectangular Shaped Line.

actually using a coaxial line, the arrangement is derived from the design shown in Figure 110. Both inner and outer conductors are rectangularly shaped - instead of circularly shaped as in the conventional coaxial line. The operation remains the same, however. Furthermore, the inner conductor need not be solid but may be hollow because high-frequency currents flow along the outer surface of a conductor. Depth penetration at the UHF band is almost negligible.

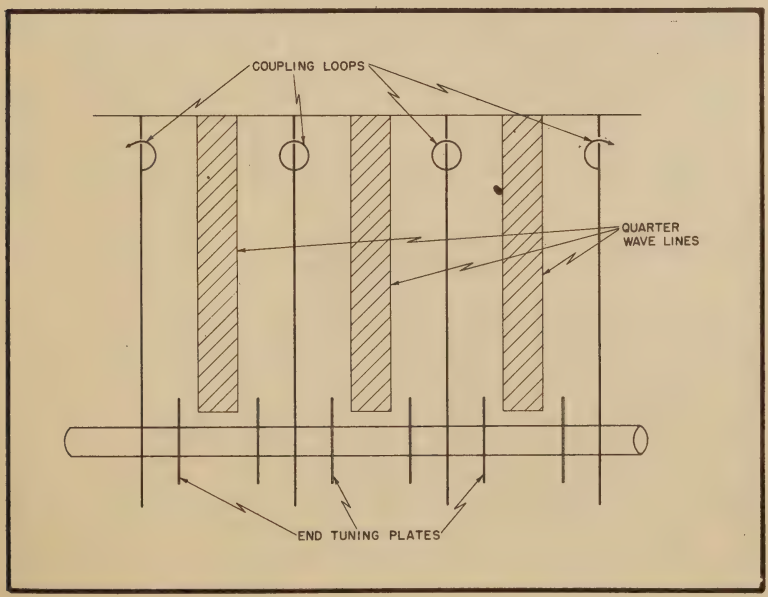


Figure 111. The Second Step in the Formation of the General Instrument UHF Tuner. (Courtesy General Instrument Corporation)

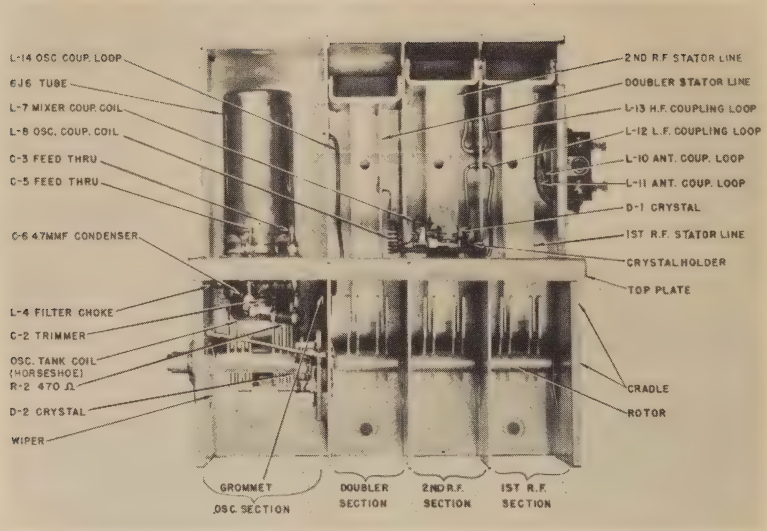


Figure 112. A Photograph of the Entire G.I. UHF Tuner Parts. Numbers and Values Correspond with Those in Figure 113.

To vary the electrical length of a transmission line we can use a shorting bar, as we have seen. Still another possibility is to place a variable capacitor across the open end of the line and vary its capacitance. This was the procedure followed indesigning the General Instrument tuner with the result shown in Figure 111. Here

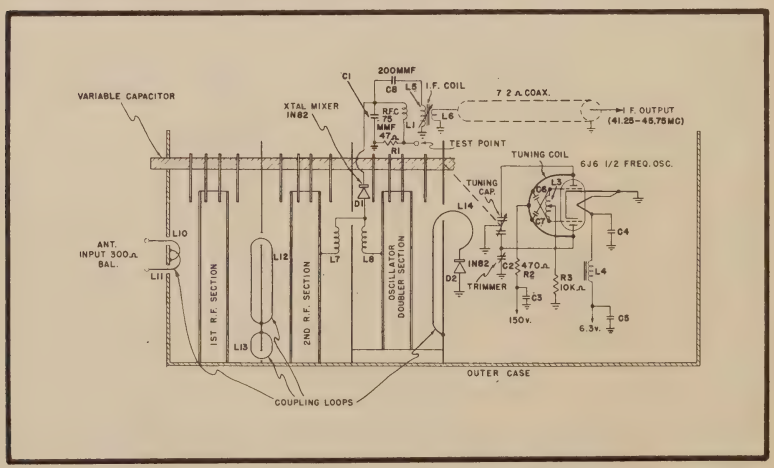


Figure 113. Application of the General Instrument UHF Tuner.

we have three quarter-wave tuning sections, each rectangular in shape and each tuned by a variable capacitor placed across the open end of the line. The other end of each line is shorted. Note the mechanical simplicity of this arrangement plus the fact that all three variable tuning capacitors can be mounted on a common shaft and rotated together.

In the final design of this tuner, shown in Figure 112, several changes were made. First, the top plate of the outer conductor and the top plate of the inner conductor was removed. (This still permitted the transmission line to function normally except that the energy is not as much confined as it is in a completely enclosed line.) Second, four plates are provided for tuning each line. The two outer plates of each set are slotted to permit point by point corrections throughout the tuning range so that all three units track. This procedure is similar to that employed with low frequency variable capacitors in radio sets. The two inner plates are solid and they can be used to correct for general trends throughout the tuning range.

Of the three such quarter-wave tuning sections employed, two are for the preselector circuit (called here 1st and 2nd R.F. sections) and the third one is for the oscillator. See Figures 112 and 113. Considering the first two sections, the antenna input possesses a 300-ohm impedance to match the transmission lines in most common use. The energy is coupled into the first tuning section by inductive coupling (primarily) between the input loops and the first quarter-wave tuner. Coupling loops are also employed between the first and second R.F. sections. Two loops are used, one for the higher UHF frequencies and one for the lower UHF frequencies. This was done to avoid various spurious resonances and suck-outs which was found to occur when only a single loop was employed. Also it is found that if the smaller loop is used to set the bandwidth of these preselector circuits at the high-frequency end and the larger loop is used for the same purpose at the low frequency end, good bandwidth is obtained over the entire UHF range.

A crystal mixer taps into the 2nd R.F. section and the oscillator tuning section to obtain energy from both for the production of the I.F. signal. The oscillator uses a 6J6 double triode operating at one-half the frequency required to mix with the incoming UHF signal. The circuit is a push-pull one with a semi-circular stamped plate coil and a split-stator tuning capacitor. In addition, the grid circuit employs a fixed tuned peaking coil circuit resonant below the lowest oscillator frequency. This arrangement, it was found, provides uniform oscillator output and uniform mixer crystal injection over the entire tuning range.

The oscillator signal is supplied to the crystal mixer via a harmonic generating crystal and a high "Q" second harmonic selecting tuned circuit. In this particular tuner the final oscillator signal is

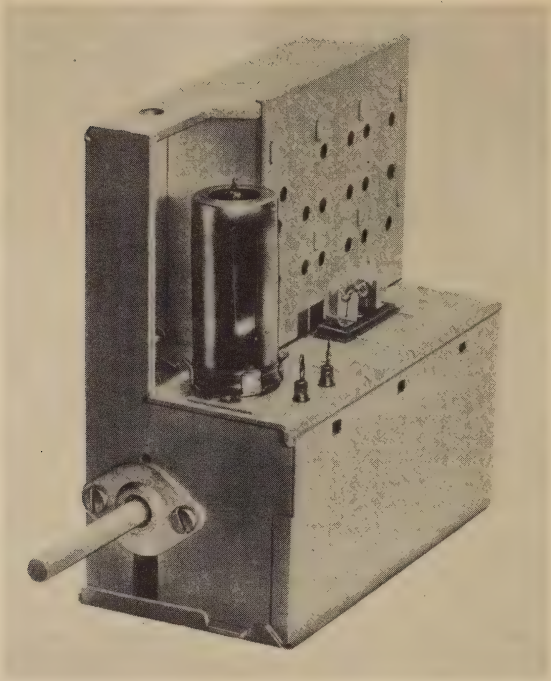


Figure 114. The Fully Enclosed General Instrument UHF Tuner.

above the incoming UHF signal frequency by an amount equal to the I.F. The latter, here, is in the 41.25 - 45.75 mc region.

Since the oscillator operates fundamentally at one-half the mixing oscillator frequency and since the oscillator doubler tank circuit should also be tuned, we have several variable capacitors associated with this section of the tuner. Figure 112 illustrates how the split-stator oscillator fundamental tuning capacitor and the capacitor tuning plates for the doubler section are also mounted on the same rotor shaft carrying the tuning plates for the 1st and 2nd R.F. sections.

Figure 112 also shows the positions of all the other components associated with this tuner. This overall assembly is completely enclosed on all sides by metal shields to reduce radiation and spurious responses. The fully enclosed tuner is shown in Figure 114.

The output of this tuner is usually coupled into a 40 mc preamplifier. When used with the General Instrument VHF turret tuner, a 13th position is available to receive this signal. In this special position the VHF, R.F. amplifier and mixer are both converted to straight 40 mc amplifiers. (The VHF oscillator, in

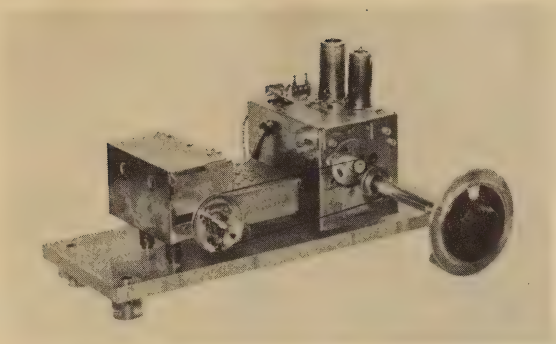


Figure 115. A View Showing How the General Instrument UHF Tuner Can be Mechanically Linked to the G.I. VHF Tuner. UHF Unit is Resting on its Side. (Courtesy General Instrument Corporation)

this position, is disabled by removal of the B+ voltage.) The signal then goes to the normal 40-mc* video I.F. stages of the VHF receiver.

Mechanically, the UHF tuner can be coupled to the VHF tuner in the manner shown in Figure 115. Setting the VHF turret tuner to the special 13th position brings the UHF output into the VHF circuitry. Then, to tune the UHF unit, the fine tuning control on the

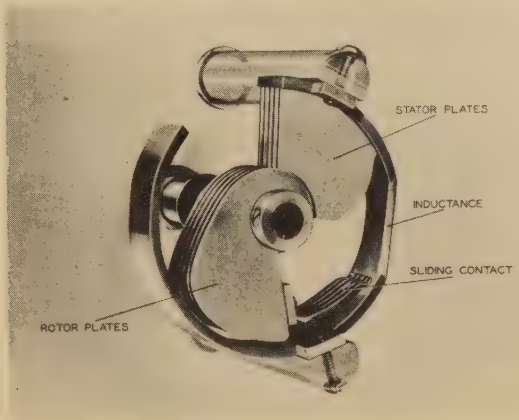


Figure 116. A Tuner That Can Resonate from 60-660 mc. (Courtesy General Radio Company)

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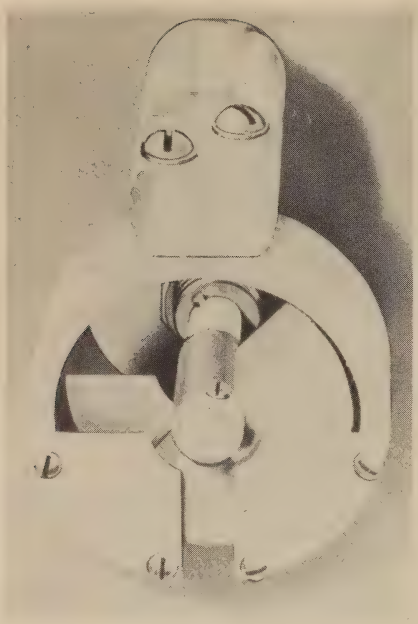
* This is a shorthand notation for the 41.25 - 45.75 mc video I.F. range.



(A)

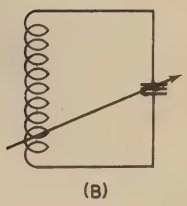


Figure 117. (A) A Tuning Unit Possessing No Sliding Contacts. It Covers the Range from 400 mc to 1200 mc. (B) Schematic Symbol for Tuner.

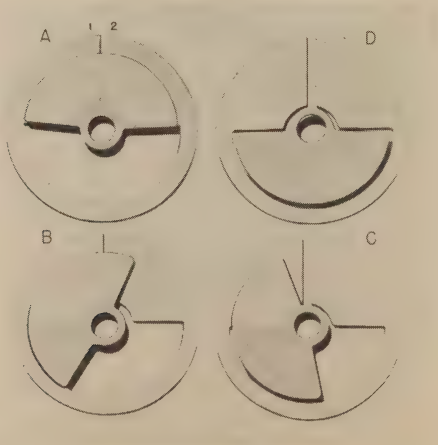


Figure 118. The Stator and Rotor Plates of a Semi-butterfly Tuner in Various Positions. (Courtesy General Radio Company)

VHF tuner is rotated. For this particular application, the fine tuning control would be required to turn through a full 360 degrees, thereby rotating the variable UHF tuning capacitors through the entire UHF range. For convenience of tuning indication, an additional sleeve is added to the VHF tuner. This is directly driven from the UHF tuner and can be used to give almost any desired type of tuning indication.

Butterfly Tuners. The butterfly tuner represents still another attempt to bridge the gap between lumped components on the one hand and distributed circuitry on the other. The butterfly tuner contains a rotor and a stator that could roughly be compared to the rotor and stator elements of a variable capacitor. However, the same assembly also contains inductance and there is no clear division between the two. In fact, where the rotor is turned, it varies inductance and capacitance simultaneously.

To understand the operation of a butterfly circuit, it might be best to trace its development from the conventional capacitor and inductor combination. In Figure 116, there is shown a variable capacitor possessing a sliding contact on the end of the movable or rotor plates. This sliding contact moves over a single turn inductance. The stator or stationary plates of the capacitor connect to one end of this single-turn inductance and the sliding contact furnishes the other connection to the inductance. The effective or acting inductance, therefore, is the length of the inductance ring contained between the stator plates and the sliding contact. When the rotor plates are turned by the capacitor shaft, not only does the capacitance of the capacitor change, but the inductance also changes due to the altered position of the sliding contact. The capacitor can be moved through an arc of 270 degrees and the contact is so arranged that the inductance and capacitance increase and decrease together. A capacitor and inductance arranged in this manner can tune from 60 to 660 mc.

The next step in the development of the butterfly circuit was the combining of the inductance and capacitance into a single unit and the removal of all sliding contacts. Such a unit is shown in Figure 117A. In this, the so-called "semi-butterfly" circuit, the stator plates are slit in half and are connected to each other by a semicircular band which represents the inductance of the circuit. Schematically, this portion of the butterfly circuit can be drawn as shown in Figure 117B. The rotor plate is semi-circular, too, and forms a capacitive coupling link between each of the stator plates.

In Figure 118A, the rotor plate is shown in the position which produces the lowest resonant frequency for the tuner. The capacitance of the tuner is maximum because the full area of the rotor is directly above both halves of the stator. Inductance, too, is maximum. As the rotor plate is moved to position B, tuner capacitance decreases because part of the rotor has been turned away from the stator sections. Inductance decreases because the presence of the rotor within the magnetic field region developed by the inductance

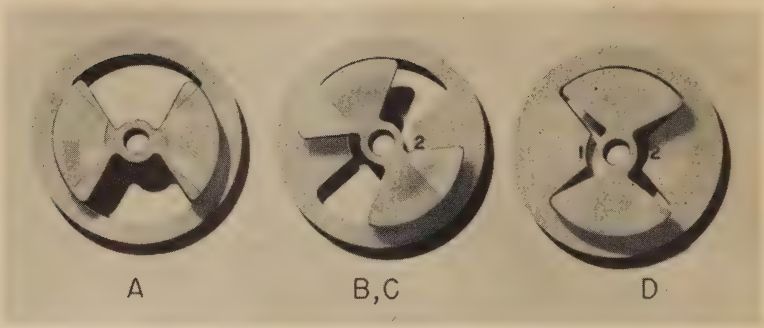


Figure 119. The Rotor and Stator Plates of a True Butterfly Tuner. The Frequency is Lowest at A and Highest at D. (Courtesy General Radio Company)

ring restricts or reduces the number of magnetic lines since the rotor acts as a shorted turn. As the rotor occupies more and more of the open area of the inductance loop, less and less of the inductance is actually effective in the circuit. The effect is to reduce the resonant frequency. Finally, in position D, the rotor plate has all but filled up this region and the lines of magnetic flux are now confined to the very small air clearance between the rotor plate and the rest of the circuit structure. In this position, the butterfly tuner is set for its highest frequency.

In a conventional coil and capacitor tuner, the connecting points to the circuit are made between rotor and stator of the capacitor. In the semi-butterfly arrangement, connections are made to points 1 and 2 shown in Figure 118A. No connections are made to the rotor, which may be mounted on an insulated shaft. This minimizes the flow of any undesirable currents in the rotor shaft and keeps losses low.

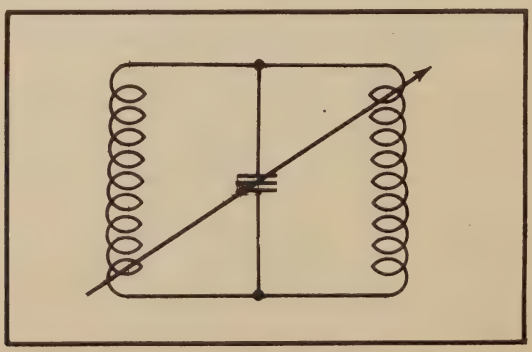


Figure 120. The Approximate Equivalent Circuit of a True Butterfly Tuner.

To obtain energy from this circuit, we can employ either electrostatic or magnetic coupling. Electrostatic coupling is recommended when one terminal is grounded. Direct connection can then be made from the other terminal to whatever circuit is designated to receive the energy. If the circuit is floating, i.e., there is no ground connection, then magnetic coupling is recommended. To accomplish this a small loop of wire is placed near the inductance loop of the butterfly circuit.

The second type of butterfly circuit, known as the true butterfly, is shown in Figure 119. The two stator sections now are symmetrically placed, with inductance arms between them. The approximate equivalent circuit is shown in Figure 120 and it is to be noted that the two inductance arms are in parallel with each other and connected across the capacitance. The explanation of circuit operation follows closely that previously given for the semi-butterfly circuit. In Figure 119A, the two rotor plates are directly above the two stator sections and the circuit capacitance and inductance are at a maximum. In Figure 119B,C the rotor plates have been rotated slightly so that they extend partially into the inductance region. At the same time, less rotor plate area is directly above the stator plates and consequently the capacitance has decreased. In Figure 119D, the inductance and capacitance values are at their lowest point. Connections to this tuner would be made at terminals 1 and 2.

Increased tuning range can be obtained by constructing butterfly circuits with a number of stacked stator and rotor sections and this is the form in which these units are generally seen. Too much stacking of plates is not feasible because the resonant impedance decreases with increase in the number of plates. While butterfly resonators have been built to tune as high as 3000 mc, they are seldom

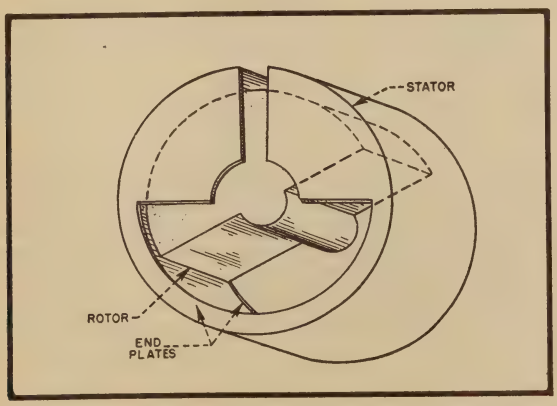


Figure 121. A Solid-rotor Semi-butterfly Tuner That Was Used As the Basis for the DuMont Tuner Shown in Figure 122. (Courtesy Electronics Magazine)

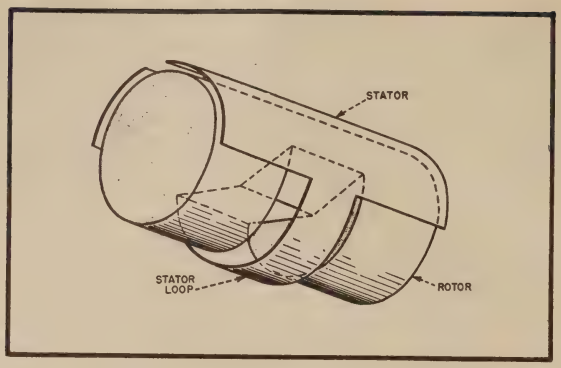


Figure 122. The Modified Semi-butterfly Tuner Evolved by DuMont. (Courtesy Electronics Magazine)

used extensively above 1000 mc. In order to reach these high frequencies, the size of the unit decreases, the number of stacked sections increases, and spurious frequencies begin to appear throughout the tuning range.

A Butterfly UHF - TV Converter. Butterfly tuners have been designed for UHF - TV converters and in time it is quite probable that these will be widely used. As an indication of what has been done, the following description covers a unit which was developed by DuMont. A semi-butterfly tuner was taken and modified to increase its frequency range to cover the UHF - TV band. The original unit appeared as shown in Figure 121. The rotor is a solid metallic semi-cylinder. The stator is a cylindrical metallic ring with a slot across the top and end plates all the way around. The end plates, on either side of the cylinder, are rather wide in the vicinity of the slot, but otherwise narrow at all other points around the cylinder. There is sufficient clearance between the rotor and stator assemblies so that the solid rotor can be turned without difficulty.

When the rotor is wholly within the section covered by the wide end plates (as it almost is in Figure 121), the frequency of the tuner is at its lowest value. Here the effective capacitance and inductance are both maximum. Gradually, as the rotor is turned away from this upper section, the capacitance decreases. Also, since the rotor is now cutting across the lower inductance loop of the tuner, it also tends to reduce the magnetic field developed by this loop and with this, its inductance. Hence the resonant frequency of the tuner decreases.

In the DuMont converter, the butterfly assembly is modified to the form shown in Figure 122. The end plates and sections of the inductance loop have been removed and this tends to increase the

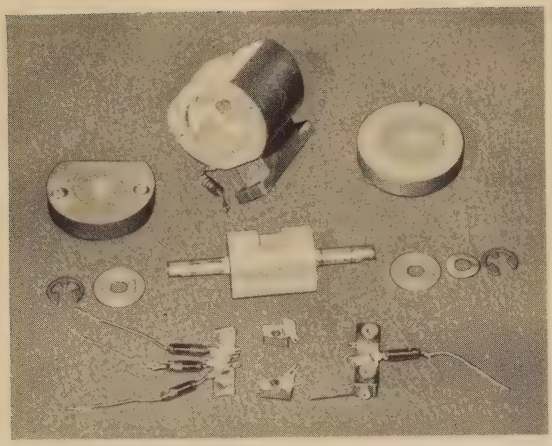


Figure 123. The Various Electrical and Mechanical Components of the Oscillator. (Courtesy DuMont)

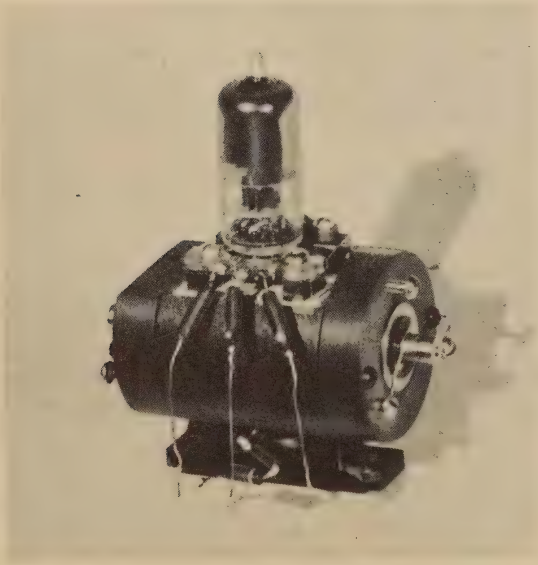


Figure 124. The Completely Assembled Oscillator Unit. (Courtesy DuMont)

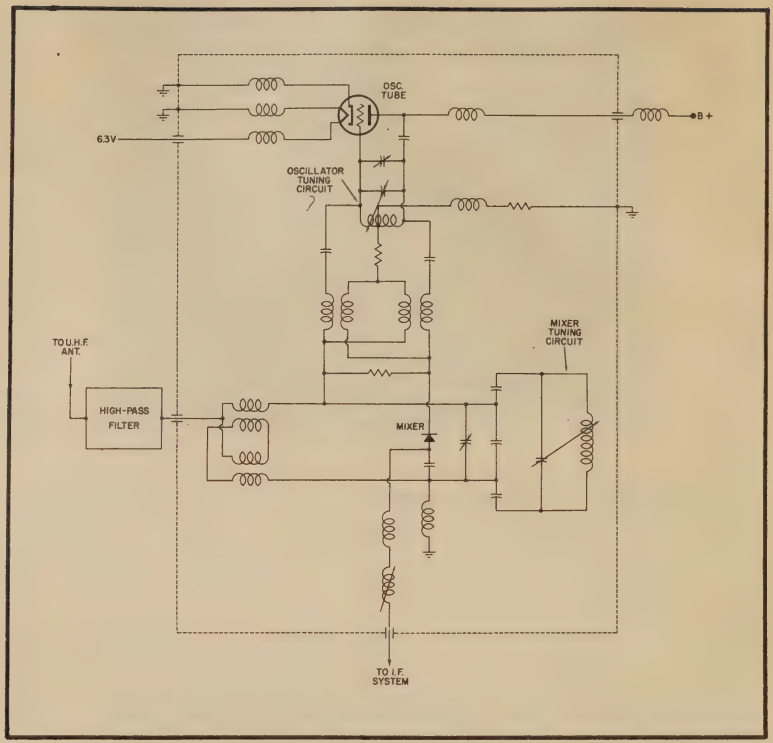


Figure 125. Schematic Diagram of the Oscillator-mixer Circuit of the DuMont Butterfly UHF Tuner. (Courtesy Electronics Magazine)

stator inductance without seriously affecting its capacitance. (The end plates tend to restrict the magnetic field developed by the stator and this keeps the inductance low. Removal of the end plates will therefore cause the inductance to rise. The increase is further aided by narrowing the width of the inductance loop since by doing this we are effectively reducing the shunt inductance present.) The stator, in the modified tuner, is now a completely solid cylinder with just a small groove or slot extending across a portion of it. See Figure 122. When the unit is tuned to its lowest frequency, this groove in the rotor is directly opposite the narrow section of the inductance loop.

A view of this tuner and its components when employed as an oscillator are shown in Figure 123. The solid rotor is evident in the center of the illustration. Above it is the stator and its supporting structure. Note that the stator consists simply of a silver film on the inside of this housing possessing the shape indicated in Figure 122. The rotor surface is also silvered to maintain a high degree of stability.

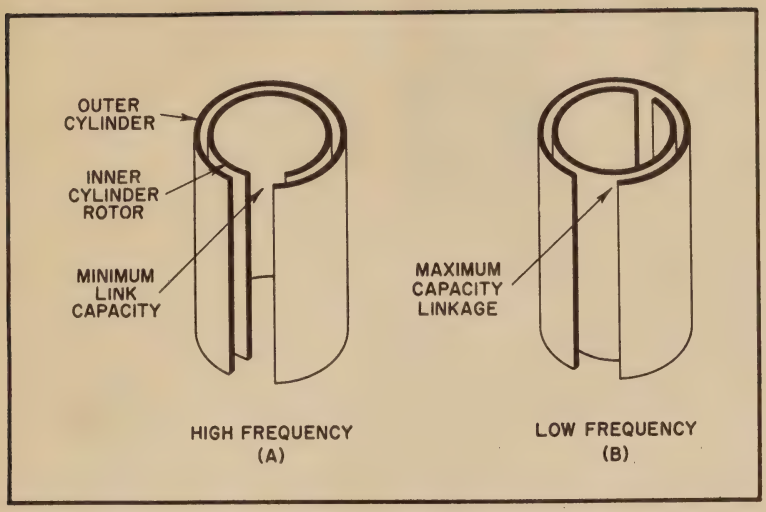


Figure 126. A Cylinder Tuning Circuit.

Assembled, the oscillator unit appears as shown in Figure 124. Note how compact this structure is and how closely the tube is physically associated with its tuner. This relationship between the various elements of a circuit becomes more intimate as the frequency of operation rises. That this should be so is made evident by the fact that at the high end of this oscillator tuning range, a major portion of the oscillator circuit is within the tube itself. In other words, the inductances and capacitances presented by the tube dominate the circuit.

The schematic diagram of the oscillator-mixer circuit is shown in Figure 125. The UHF signal is received by the antenna and then passed through a high-pass filter to a balanced-to-unbalanced transformer thence to the mixer. The input end of this transformer presents an unbalanced impedance of 50 ohms. The output end presents a balanced impedance of 200 ohms.

The mixer contains its own resonant circuit consisting of a butterfly tuner similar in structure to the oscillator tuner. The two units are ganged together and would be simultaneously tuned by a common front panel dial. Within the mixer circuit the oscillator and incoming signals are combined and the resultant difference frequency transferred to an I.F. amplifier. The value of this difference frequency would fall within one of the VHF channels so that it could be received by a VHF receiver.

The oscillator is a balanced Colpitts circuit. The signal it generates is transferred to the mixer circuit via another balanced-to-unbalanced transformer.

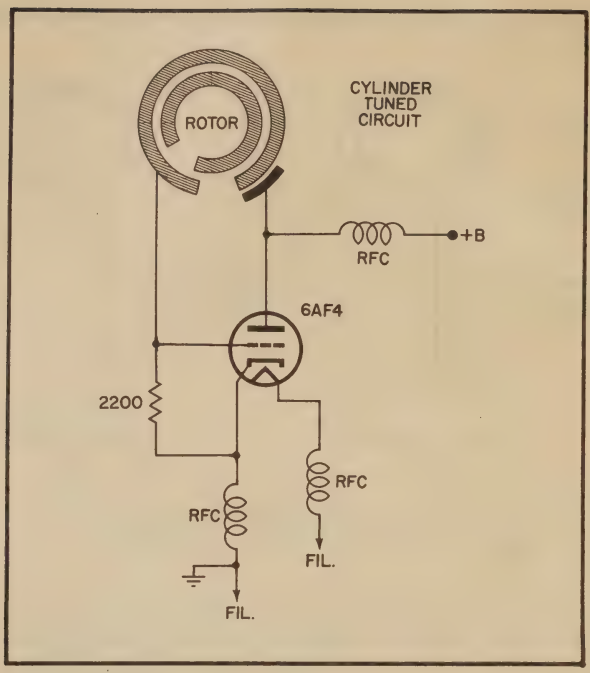


Figure 127. A UHF Oscillator Using Cylindrical Tuning Elements.

Cylinder Tuner. There is still another cylinder-type tuned circuit and this is demonstrated in Figure 126. Two slotted cylinders are used, with one placed inside the other. The outer cylinder is kept stationary while the inner cylinder is rotated for frequency variation. The maximum frequency is obtained when the slots of both cylinders are lined up, as shown in Figure 126A. In this position the total effective capacity is that which exists across the slot of the outer cylinder. Now, as the inner cylinder is rotated, its surface moves across the gap of the outer cylinder gap and a capacitance develops from each side of the outer cylinder gap to the inner cylinder surface. These two capacitances are in series and, in effect, add to the capacitance already existing across the outer cylinder slot. The increase in total capacitance causes the frequency to decrease.

Some inductance variation also takes place; however, the inductance of a cylinder is quite low and the inductance variation is limited.

Figure 127 illustrates a typical circuit application of the slotted cylinder. A 6AF4 tube functions as an oscillator with the grid connecting directly to one side of the outer cylinder and the plate coupling to the other side through a small capacitance.